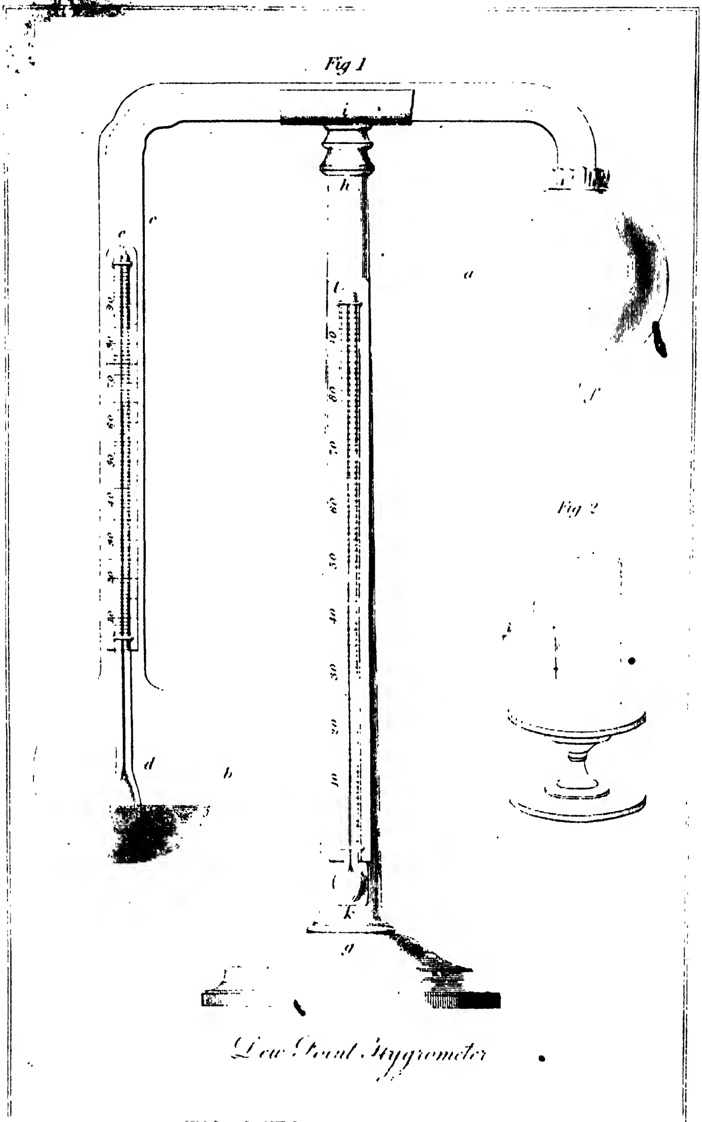

Dew Point Hygrometer

London. John W. Parker, West Strand. 1845.

ELEMENTS

OF

METEOROLOGY;

BEING THE THIRD EDITION, REVISED
AND ENLARGED, OF

METEOROLOGICAL ESSAYS,

BY THE LATE

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CONTENTS OF THE SECOND VOLUME.

An Essay upon Hygrometry, and the Construction and Uses of a New Hygrometer.

On the Radiation and Absorption of Heat in the Atmosphere.

On the Water-Barometer erected in the Hall of the Royal Society.

On Climate; considered with regard to Horticulture.

Remarks upon the Barometer and Thermometer, and the mode of using Meteorological Instruments in general.

On the Gradual Deterioration of Barometers, and the means of preventing the same.

An Essay on the Climate of London.

Abstracts of Meteorological Observations.

An Essay on some of the Phenomena of Atmospheric Electricity.

PLATES IN THE SECOND VOLUME.

To face the Title.

At the end of the Volume.

AN ESSAY

UPON HYGROMETRY

AND THE

CONSTRUCTION AND USES OF A NEW HYGROMETER.

UPON HYGROMETRY ~~AND THE~~ CONSTRUCTION AND USES OF A NEW HYGROMETER.

§ 1. INTRODUCTION.

"Nec non et in conviviis mensisque nostris vasa quibus esculentum additur sudorem repositoriis liquentia diras tempestates prænuntinant."—C. Plin. *Nat. Hist.*, Lib. xviii.

IN the year 1812, my attention was attracted by the passage above extracted from Pliny, which appeared to me, by the interpretation which I affixed to it, to point to a natural phenomenon which might be rendered subservient not only to prognostications of the weather, according to the suggestion of that accurate observer, but to some of the more refined purposes of modern science. I was, however, for some time doubtful how far the interpretation which had occurred to me could be borne out by the translation of the expression *esculentum;* as it was a necessary condition to this interpretation, that whatever was served up in the *vasa* should have been cold.

The passage is thus rendered into English in a very old translation which I consulted: "And to conclude, and make an end of this discourse; whensoever you see, at any feast, the dishes and platters whereon your meat is served up to the board, sweat or stand of a dew, and leaving that sweat which is resolved from them either upon dresser, cupboard, or table, be assured

that it is a token of terrible tempests approaching*." Upon referring to several competent judges, they confirmed my conjecture, and agreed with me in thinking, that the dew or sweat, so accurately described as forming, in particular kinds of weather, upon vessels in which food was served up, could only have arisen from depression of temperature.

This, perhaps, will therefore be considered as one of the most curious cases upon record, in which the sagacity of the ancients anticipated an observation which has been held to be peculiarly demonstrative of the superior refinements of the present state of experimental philosophy, and may settle a disputed claim to the honour of priority of discovery amongst the existing race of natural philosophers.

However this may be, my mind was thus directed to the deposition of moisture which takes place upon certain bodies when brought into an atmosphere which is warmer than themselves; and following up the suggestion of Pliny, I readily conceived that the fact was connected with meteorological phenomena; and that experiments, founded upon it, might be devised to elucidate the relation of air to vapour. I shortly after applied myself seriously to the inquiry, and was soon satisfied of the accuracy of the conjecture.

The manner in which I proceeded at that time, was as follows:—I made a mixture of two salts calculated to produce cold by their solution; I then arranged

* Translation of C. Pliny, by Philemon Holland. 1601.

half a dozen drinking-glasses upon a board, each furnished with a thermometer, and poured water into one of them. I added a teaspoonful of the freezing mixture, which invariably produced a copious dew upon the exterior of the glass. I emptied the contents of the first glass into the second, and so into the third, &c., till the liquor, gradually acquiring heat by the process, arrived at such a temperature as no longer to produce any condensation upon the vessel. This point, as marked by the thermometer, was noted, and found to vary, very considerably, in relation to the temperature of the air, according to different states of the atmosphere.

I kept a journal of the weather for several months; registering the variations of the barometer, thermometer, De Luc's hygrometer, and the temperature at which moisture was condensed, and obtained some very interesting results.

I afterwards varied my apparatus in the following manner:—I procured five small hollow cylinders of brass, three inches in diameter, and four inches in height, fitted with a small cock in the bottom of each. These were very highly polished, and placed in a frame, one immediately over another, so that by turning the cock, the contents of the upper would flow into that immediately beneath it. I put the cold liquid into the top cylinder; and when steam was produced upon its surface, suffered the solution to run into the next, and so on to the third, &c., till all condensation ceased; when the temperature was marked as before. I found this apparatus very sensible, the bright surface of the

metal being visibly obscured by the slightest film of moisture. These experiments were, however, troublesome, and required much time to insure accuracy. The results I forbear from particularly detailing, as they are superseded by the more exact observations which I have been enabled to make with the instrument which I am about to describe.

It was not till many months after I had commenced this course of inquiry, that I discovered that the mode of investigation which had been suggested to me by the observation of the Roman naturalist, was not so new as I had conceived it to be. The same principle had been applied by the Academicians del Cimento (the restorers of experimental philosophy, as they have been very properly called), to the purposes of hygrometry.

They took a glass vessel of a conical form, and kept it full of snow or pounded ice. This vessel was suspended in the open air with its point downwards, and the moisture which was condensed upon it, trickled down its sides, and dropped from the point of the cone. The frequency of the drops, was applied by them, as a measure of the humidity of the atmosphere. M. le Roi also, adopting the same idea, simplified its application by putting water into a glass vessel, and gradually lowering its temperature, by means of ice, till the appearance of a slight dew upon the surface denoted the point of saturation. The temperature of this point he measured, by means of the thermometer. He judged of the humidity of the air by the greater or less degree of depression necessary to produce pre-

cipitation. Lastly, Dr. Dalton, in his "Essay upon the force of steam or vapour from water and other liquids at different temperatures," (read before the Literary and Philosophical Society of Manchester, and published in the fifth volume of their *Memoirs*, one of an interesting series, which it would be difficult to match for originality and sound philosophical induction,) thus describes his method of finding the force of the aqueous vapour:—

"I usually take a tall cylindrical glass jar, dry on the outside, and fill it with cold spring-water, fresh from the well; if dew be immediately formed on the outside, I pour the water out; let it stand awhile to increase in heat, dry the outside of the glass well with a linen cloth, and then pour the water in again: this operation is to be continued till the dew ceases to be formed, and then the temperature of the water must be observed. Spring-water is generally about 50°, and will mostly answer the purpose the three hottest months of the year: in other seasons an artificial cold mixture is required."

The discovery of want of originality damped for a time the ardour of a laborious pursuit; but I had been impressed with the great utility of any contrivance which might enable an observer to mark with precision, neatness, and expedition, the constituent temperature of atmospheric vapour. Upon reading the account of the ingenious contrivance of Dr. Wollaston, which he has termed the Cryophorus, the subject again occurred to me; and I received from that instrument the hint, which, after many trials, led to the completion of my hygrometer.

§ 2. CONSTRUCTION AND ATMOSPHERICAL USES.

Fig. 1, in the plate which faces the title-page of the present volume, represents the instrument in its full dimensions; *a* and *b* are two thin glass balls of $1\frac{1}{4}$ inch diameter, connected together by a tube, having a bore about $\frac{1}{8}$th inch. The tube is bent at right angles, over the two balls, and the arm *b c* contains a small thermometer *d e*, whose bulb, which should be of a lengthened form, descends into the ball *b*. This ball having been about two-thirds filled with ether, is heated over a lamp till the fluid boils, and the vapour issues from the capillary tube *f*, which terminates the ball *a*. The vapour having expelled the air from both balls, the capillary tube *f* is hermetically closed by the flame of a lamp. This process is familiar to those who are accustomed to blow glass, and may be known to have succeeded after the tube has become cool, by reversing the instrument and taking one of the balls in the hand, the heat of which will drive all the ether into the other ball, and cause it to boil rapidly. The other ball *a* is now to be covered with a piece of muslin. The stand *g h* is of brass, and the transverse socket *i* is made to hold the glass tube in the manner of a spring, allowing it to turn and be taken out with little difficulty. A small thermometer *k l* is inserted into the pillar of the stand. The manner of using the instrument is this:—After having driven all the ether into the ball *b* by the heat of the hand, it is to be placed at an open window, or out of doors, with the ball *b* so situated that the surface of the liquid may

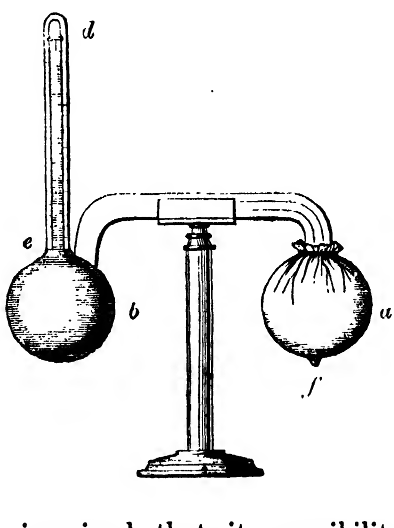
be upon a level with the eye of the observer. A little ether is then to be dropped upon the covered ball. Evaporation immediately takes place, which, producing cold upon the ball *a*, causes a rapid and continuous condensation of the ethereal vapour in the interior of the instrument. The consequent evaporation from the included ether, produces a depression of temperature in the ball *b*, the degree of which is measured by the thermometer *d e*. This action is almost instantaneous, and the thermometer begins to fall in two seconds after the ether has been dropped. A depression of 30 or 40 degrees is easily produced, and I have seen the ether boil, and the thermometer driven down below 0° of Fahrenheit's scale. The artificial cold, thus produced, causes a condensation of the atmospheric vapour upon the ball *b*, which first makes its appearance in a thin ring of dew, coincident with the surface of the ether. The degree at which this takes place is to be carefully noted. A little practice may be necessary to seize the exact moment of the first deposition; but certainty is very soon acquired. It is advisable, when the instrument has been constructed with a transparent ball, to have some dark object behind it, such as a house, or a tree; as the cloud is not so readily perceived against the open horizon. The depression of temperature is first produced at the surface of the liquid, where evaporation takes place; and the currents, which immediately ensue to effect an equilibrium, are very perceptible. The bulb of the thermometer *d e*, is not quite immersed in the ether, that the line of greatest cold may

pass through it. In very damp or windy weather the ether should be very slowly dropped upon the ball, otherwise the descent of the thermometer will be so rapid as to render it difficult to be certain of the degree. In dry weather, on the contrary, the ball requires to be well wetted more than once, to produce the requisite degree of cold. If at any time there should be reason to suspect the accuracy of an observation, it may easily be corrected by observing the temperature at which the dew upon the glass again disappears: the mean of the two observations (whose errors, if any, will lie in contrary directions,) will give the true result. It is obvious that care should be taken not to permit the breath to affect the glass. With these precautions the observation is simple, expeditious, easy, and certain.

Being desirous of ascertaining whether the superior power of metals in conducting heat, together with the high polish of which they are susceptible, might not be rendered conducive to the perfection of the hygrometer, I endeavoured to modify its form in such a way as to allow of their being employed in its construction. After some unsuccessful trials I completed one, which is given in the figure on the opposite page.

The balls *a* and *b*, together with their connecting tube, are made of very thin brass. To the orifice *f* is soldered a small piece of platinum tube, which, from its property of welding with glass, allows of the junction of a piece of glass tube, and, after the instrument has been boiled as before directed, may be hermetically closed in the usual way. The thermometer *d e*

is so constructed that its bulb, which is inclosed in the ball *b*, is rather less than the diameter of its stem, which is made proportionably thick. It is ground air-tight into a collar of brass, made for its reception on the top of the ball. The ball *a* is covered with muslin, and the ball *b* is very highly polished. The advantages which I looked for in this construction of the instrument were two: first, I expected that an unpractised observer might more readily be able to mark with precision the instant of the first precipitation of the dew. The white mist is directly seen, whereas a little experience is required to obtain an equal degree of certainty with the transparent glass.



Secondly, I imagined that its sensibility might be increased by extending, at pleasure, the scale of the thermometer *d e*. The divisions of the thermometer included in the glass instrument are necessarily small;

but those of the external thermometer may be made of any required magnitude, without rendering the bulk of the whole inconveniently great.

It was also an important object to ascertain whether any hygrometric property of the glass, or difference between it and the metal in attraction of moisture, would have any appreciable effect upon the condensing power.

Long experience has, however, convinced me that the metallic hygrometer possesses no real superiority over the glass one. The visibility of the deposition in the latter is rendered perfect by making the condensing ball of black glass, and viewing it by reflected light in the manner of a mirror; and I never could perceive any difference in the sensibility of the two instruments.

Thus much on the construction of the hygrometer: it is simple and easy. Its graduation depends upon no arbitrary or disputed determinations of wet and dry: it is liable to no deterioration from use, age, or accidental circumstances; and above all things, whenever, or by whomsoever made, it is incapable, in proper hands, of affording erroneous results. It may be more or less boiled; the *vacuum* may be more or less perfect; and it may, consequently, require the affusion of a larger or smaller quantity of ether to make it act: but (provided the thermometer be correct) the observation, when obtained, cannot deceive. Its determinations are, therefore, as strictly comparable one with another, under all circumstances, as those of the barometer or the thermometer.

In describing the various uses and applications of the hygrometer, I shall commence with the most popular; its use, namely, as a weather-glass.

When consulted with a view of predicting the greater or less probability of rain, or other atmospheric changes, two things are to be principally attended to —the difference between the constituent temperature of the vapour, and the temperature of the air; and the variation of the dew-point. In general, the chance of rain, or other precipitation of moisture from the atmosphere, may be regarded as in inverse proportion to the difference between the two thermometers: but in making this estimate, regard must be had to the time of day at which the observation is made. In settled weather the dryness of the air increases with the diurnal heat, and diminishes with its decline; for the constituent temperature of the vapour remains nearly stationary. Consequently, a less difference at morning or evening is equivalent to a greater in the middle of the day.

But to render the observation most completely prospective, regard must be had at the same time to the movement of the dew-point. As the elasticity of the vapour increases or declines, so does the probability of the formation and continuation of rain. An increasing difference, therefore, between the temperature of the air, and the temperature of the point of condensation, accompanied by a fall of the latter, is a sure prognostication of fine weather; while diminished heat, and a rising dew-point, infallibly portend a rainy season. The mean results for the different periods of the

year, determined by sufficient observation, afford accurate standards of comparison whereby to judge of the state of the vapour; and the particulars recorded in the Essay upon the Climate of London, will not be without their use in this respect. In winter, when the range of the thermometer during the day is small, the indication of the weather must be taken more from the actual rise and fall of the point of condensation, than from the difference between it and the temperature of the air. It must be remembered that a state of saturation may exist, and precipitation even take place in the finest weather, and under a cloudless sky; but this is when the diurnal decline of the temperature of the air, near the surface of the earth, falls below an unfluctuating term of precipitation; and it is probable, that at some period or other of the twenty-four hours, this term is always passed. The radiation of the earth, in the absence of the sun, cools the stratum of air in contact with it; and a slight precipitation takes place, of so little density as totally to escape the observation of the eye. At other times it becomes visible, and assumes the appearance of mist or fog. Under such circumstances, the hygrometer will sometimes exhibit a different kind of action. If it be brought from an atmosphere of a higher temperature into one of a lower degree, in which condensed aqueous particles are floating, the mist will begin to form at a temperature several degrees higher than that of the air. The heat emanating from the ball of the instrument, dissolves the particles of water, and forms an atmosphere around it of greater elasticity than the surrounding medium;

so that, when it is put in action, the point of deposition is proportionably raised. This action does not at all interfere with the determination of the real force and quantity of vapour; for, in all such cases, the full saturation of the atmospheric temperature must have place, and, consequently, the temperature of the vapour must be coincident with that of the air.

This kind of precipitation, which may often be detected by the hygrometer, when it would otherwise escape notice, far from being indicative of rain, generally occurs in the most settled weather. It is analogous to the formation of dew, and is dependent upon the same cause, the radiation of the earth, which can only take place under an unclouded sky.

A sudden change in the dew-point, is generally accompanied by a change of wind: but the former sometimes precedes the latter by a short interval; and the course of the aërial currents may be anticipated before it affects the direction of the weather-cock, or even the passage of smoke.

My own experience, and the testimony of others, assure me that the hygrometer, thus applied, is more to be depended upon than any instrument that has yet been proposed. Even when its indications are contrary to those of the barometer, reliance may be placed upon them; but simultaneous observations of the two most usefully correct each other. The rise and fall of the mercurial column is, most probably, primarily dependant upon the state of the upper regions of the atmophere, with regard to heat and moisture. Loeal *physical* alterations of its density, thus partially brought about,

are *mechanically* adjusted, and the barometer gives us notice of what is going on in inaccessible regions. A rise in the dew-point, accompanied by a fall of the barometer, is an infallible indication that the whole mass of the atmosphere is becoming imbued with moisture, and a copious precipitation may be looked for. If the fall of the barometer take place at the same time that the point of precipitation is depressed, we may conclude that the expansion which occasions the former, has arisen at some distant point, and wind, not rain, will be the result. But when the air attains the point of precipitation, with a high barometer, we may infer that it is a transitory and superficial effect, produced by local depression of temperature. Particular illustrations of these modified effects might easily be adduced in this place, but they will be more conveniently studied in the abundant observations of a subsequent Essay.

Thus does the hygrometer mark with infallible precision the comparative degree of moisture and dryness in the atmosphere, and by exhibiting them in degrees of the thermometer, refer them to a known standard of comparison, and speak in a language which everybody understands. But its observations may be made applicable to a much wider field of research, and adapted to still more important objects. By means of tables, we can find with the utmost accuracy and ease the positive weight of aqueous vapour diffused through any given portion of space, and its force or elasticity as measured by the column of mercury which it is capable of supporting: we dis-

cover at once the proportion of moisture in any space to the quantity which would be required to saturate it, or what has been termed the true natural scale of the hygrometer: we can calculate, with perfect ease, the specific gravity of any mixture of air and aqueous vapour: and we can measure the force and quantity of evaporation. Upon the *data* employed in the construction of the tables, it will be necessary that I should premise a few observations.

Dr. Dalton, in his valuable Essay before referred to, has detailed the results of a laborious series of experiments, by which he has ascertained with great precision the force of vapour from water at every degree between its freezing and its boiling points, and derived from them a *formula*, by which he extended the results from the freezing of mercury to the 325th degree of Fahrenheit's scale. Dr. Ure has since* entered upon the same investigation, with a different modification of apparatus, calculated to avoid some irregularities to which Dr. Dalton's was exposed. He carried his actual experiments as high as 312°; and thus ascertained that Dr. Dalton's *ratio* of progression for the force of vapour, though apparently accommodated to the intervals between 32° and 212°, could not serve for the higher ranges. In the prosecution of the inquiry, he was led to the discovery of a very simple *ratio*, which admirably connects together the whole series of experiments. In the preceding Essay (p. 80), I have given Dr. Dalton's Table of the

* *Phil. Trans.* 1818, p. 338.

Force of Vapour, which, for the range of atmospheric temperature, exhibited not only a perfect adaptation to his own experiments, but also a surprising accordance with those of Dr. Ure: but reflecting that from these and other considerations, the rule from which they were derived could not be the law of nature, I have recalculated the tables from the *data* of Dr. Ure. It is gratifying to find that, for the purposes of the hygrometer, the difference after all is very inconsiderable.

The second column of Table I. exhibits the force of aqueous vapour, hence derived, in inches of mercury, at the temperature marked in the corresponding line of the first column.

Upon these two *data*, namely, the force and temperature of the vapour, are chiefly founded the calculations which have furnished me with the series of the third column, which contains the weight in grains of a cubic foot of the vapour at the corresponding temperature and pressure. The method of computing it is as follows:—Steam at 212°, and under a pressure of 30 inches of mercury, is, as nearly as possible, 1700 times (1696) lighter than an equal bulk of water at its maximum of density; and a cubic foot of water, at the temperature of 40°, weighs, according to the accurate investigations of Dr. Rice, 437,272 grains; the weight, therefore, of a cubic foot of steam, at the above temperature and pressure, is $\frac{437272}{1700}$, or 257·218 grains. Hence we may find the weight of an equal bulk of vapour of the same temperature under any other given pressure, suppose 0·560 in.:

for the volume being in inverse proportion to the pressure,

Ins.		Ins.		Grs.		Grs.
30	:	0·560	::	257·218	:	4·801

the weight required.

Having now obtained the weight of a cubic foot of vapour, at a pressure of 0·560 in., and at a temperature of 212°, we may proceed to find its weight under the same pressure at any other temperature, suppose 60°. It was found by Gay Lussac, that all aëriform bodies (vapours out of the contact of their respective fluids, as well as gases,) expand $\frac{1}{480}$th part of their volume for every accession of temperature equivalent to one degree of Fahrenheit's scale; therefore, reckoning a volume of gas at 32° as unity, its volume at 60° is to its volume at 212°, as $1+\frac{28}{480}$ is to $1+\frac{180}{480}$, or :: 1·0583 : 1·3749, and the density and weight being in inverse proportion to the volume,

Vol. at 60°.		Vol. at 212°		Grs		Grs.
1·0583	:	1·3749	::	4·801	:	6·222

the weight of the cubic foot of vapour at the temperature of 60° and under a pressure of ·560 in.

It has also been proved by Dr. Dalton, that as much vapour of determined temperature is formed in a given bulk of air as in a vacuum of equal space; therefore, the above result gives the weight of vapour which can exist in a cubic foot of air at the temperature of 60°. The fourth column of the Table contains the proportionate expansion for the corresponding degrees.

TABLE I. *Showing the Force, Weight, and Expansion of Aqueous Vapour, at different Temperatures, from 0° to 95°.*

Temp.	Force.	Weight of a Cubic F. ot.	Expansion.	Temp.	Force.	Weight of a Cubic Foot.	Expansion.
0°	0·068	0·856	·9334	30°	0·200	2·361	·9959
1	0·071	0·892	·9355	31	0·208	2·451	·9980
2	0·074	0·928	·9375	32	0·216	2·539	1·0000
3	0·077	0·963	·9396	33	0·224	2·630	1·0020
4	0·080	0·999	·9417	34	0·232	2·717	1·0041
5	0·083	1·034	·9438	35	0·240	2·805	1·0062
6	0·086	1·069	·9459	36	0·248	2·892	1·0083
7	0·089	1·104	·9480	37	0·256	2·979	1·0104
8	0·092	1·139	·9500	38	0·264	3·066	1·0125
9	0·095	1·173	·9521	39	0·272	3·153	1·0145
10	0·098	1·208	·9542	40	0·280	3·239	1·0166
11	0·103	1·254	·9563	41	0·292	3·371	1·0187
12	0·107	1·308	·9584	42	0·304	3·502	1·0208
13	0·111	1·359	·9605	43	0·316	3·633	1·0229
14	0·115	1·405	·9625	44	0·328	3·763	1·0250
15	0·119	1·451	·9646	45	0·340	3·893	1·0270
16	0·123	1·497	·9667	46	0·352	4·022	1·0291
17	0·127	1·541	·9688	47	0·364	4·151	1·0312
18	0·131	1·586	·9709	48	0·376	4·279	1·0333
19	0·135	1·631	·9730	49	0·388	4·407	1·0354
20	0·140	1·688	·9750	50	0·400	4·535	1·0375
21	0·146	1·757	·9771	51	0·414	4·684	1·0395
22	0·152	1·825	·9792	52	0·428	4·832	1·0416
23	0·158	1·893	·9813	53	0·444	5·003	1·0437
24	0·164	1·961	·9834	54	0·460	5·173	1·0458
25	0·170	2·028	·9855	55	0·476	5·342	1·0479
26	0·176	2·096	·9875	56	0·492	5·511	1·0500
27	0·182	2·163	·9896	57	0·508	5·679	1·0520
28	0·188	2·229	·9917	58	0·526	5·868	1·0541
29	0·194	2·295	·9938	59	0·543	6·046	1·0562

TABLE I. *continued**.

Temp.	Force.	Weight of a Cubic Foot.	Expansion.	Temp.	Force.	Weight of a Cubic Foot.	Expansion.
60°	0·560	6·222	1·0583	79°	1·028	11·016	1·0979
61	0·577	6·399	1·0604	80	1·060	11·333	1·1000
62	0·594	6·575	1·0625	81	1·093	11·665	1·1020
63	0·615	6·794	1·0645	82	1·127	12·005	1·1041
64	0·636	7·013	1·0666	83	1·162	12·354	1·1062
65	0·657	7·230	1·0687	84	1·198	12·713	1·1083
66	0·678	7·447	1·0708	85	1·235	13·081	1·1104
67	0·699	7·662	1·0729	86	1·273	13·458	1·1125
68	0·722	7·899	1·0750	87	1·312	13·877	1·1145
69	0·745	8·135	1·0770	88	1·351	14·230	1·1166
70	0·770	8·392	1·0791	89	1·390	14·613	1·1187
71	0·796	8·658	1·0812	90	1·430	15·005	1·1208
72	0·822	8·924	1·0833	91	1·470	15·432	1·1229
73	0·849	9·199	1·0854	92	1·510	15·786	1·1250
74	0·877	9·484	1·0875	93	1·551	16·186	1·1270
75	0·906	9·780	1·0895	94	1·593	16·593	1·1291
76	0·936	10·107	1·0916	95	1·636	17·009	1·1312
77	0·966	10·387	1·0937	212	30·000	257·218	1·3749
78	0·997	10·699	1·0958				

* In the volume of the *Greenwich Magnetical and Meteorological Observations* for 1842, the Astronomer Royal has given a Table of the elastic force of Vapour for every tenth of a degree from 0° to 90°, calculated from the experiments of Dalton combined with that of Dr. Ure. According to this Table, the force at

0° = 0·061 90° = 1·368 50° = 0·373.

Another Table, calculated from the experiments of Dr. Ure, by Mr. Galbraith, from a formula of Mr. Ivory, and which is the one adopted in the Report of the Committee of Physics and Meteorology, published by the Royal Society, will be given at the end of this Essay.

From this table we learn, amongst other points of interest, that the weight of steam which can exist in the atmosphere is doubled at each rise of 21° of temperature nearly.

It is at all times desirable to bring the results of calculation, however exact the *data* upon which they are founded, to the test of actual experience; and we have the ready means of so doing with regard to the above Table. The indefatigable De Saussure, in his *Essais sur L'Hygrométrie,* gives the results of a series of experiments, to determine the quantity of moisture which air is capable of dissolving at certain temperatures. The means which he employed were simple. He thoroughly dried the air of a large glass balloon, of known capacity; and then suspended it in a small piece of linen, which had been moistened and accurately weighed. He ascertained the point of saturation by means of a *manometer*, which ceased to move when the term of extreme humidity had been obtained, and then withdrawing the linen, he instantly noted its loss of weight. He thus found that at the temperature of 15°·16 Reau. a French cubic foot of air took up 11·0690 grains of water; while at 6°·18 Reau. it only dissolved 5·6549 grains. By reducing these results to English weights and measures, we have at 66° of Fahrenheit, 7·498 grains in a cubic foot, and at 45½° Fahrenheit, 3·830 grains: a close accordance with our theoretical determinations.

Mr. Anderson, in his highly interesting treatise upon Hygrometry, published in the *Edinburgh Encyclopædia*, has also given us the results of his experi-

ments, to determine the same point by a method less liable, perhaps, to objection. His manner of operating consisted in causing a large volume of air, saturated with moisture, to pass slowly in a stream through a sufficient quantity of sulphuric acid, or dry muriate of lime, cut off from all communication with the atmosphere; and then observing the increase of weight which these substances acquired in consequence of the air being transmitted through them. The weight of a cubic foot of steam, at different temperatures hence derived, is compared in the following Table with those derived from calculation.

Temp.	Grs. by Expt.	Calculated.
49°	4·085	4·407
59	5·679	6·046
77	9·828	10·387
83	11·660	12·354

Considering the nature of the experiment, and the complication of the calculations, this is again a very close agreement.

The manner of using the Table will be best understood from an example. Let the temperature of the atmosphere be 70°, and the point of condensation, as found by the hygrometer, 55°; the pressure of the vapour, under these circumstances, is immediately found opposite to the degree of its constituent heat 55° = 0·476. To find its weight, we proceed thus:—Supposing that the temperature of the air had not differed from that of the dew-point, its weight would have been found upon the same line as its pressure = 5·342 grains. But its bulk is expanded

by the excess of atmospheric heat; we must, therefore, seek in the fourth column for the degree of expansion at 55° = 1·0479, and at 70° = 1·0791, and apply the correction thus:—

Bulk at 70°.		Bulk at 55°.		Grs.		Grs.
1·0791	:	1·0579	::	5·342	:	5·175

which is the weight required.

Again,—the dryness of the atmosphere, under the above conditions, may be conveniently expressed as 15°, in terms of the thermometric scale: but it may be desirable also to know what it would be upon the natural scale of the hygrometer, which is the most accurate mode of expressing the result. This is readily ascertained by dividing the elasticity of vapour at the temperature of the dew-point, by the elasticity at the temperature of the air: the quotient will express the proportion of moisture actually existing, to the quantity which would be required for saturation; for, calling the term of saturation 1·000, as the elasticity of vapour at the temperature of the air is to the elasticity of vapour at the temperature of the dew-point, so is the term of saturation to the actual degree of moisture,—thus,

Elast. at 55°.		Elast. at 70°.		
·476	÷	·770	=	·618

The relation of this mode of expressing the degree of moisture to that of denoting the degree of dryness by the thermometric scale, will be elucidated by selecting a different example. Let the temperature of the air be 47°, and the dew-point 32°; the dryness

represented by the former expression will be 15°, as before, but by the latter the degree of moisture will be reduced to ·593.

Thus, by two simple observations, and very easy calculations, we ascertain, with precision, the following points of the utmost interest to meteorology.

Temperature of the air	70°
Dew-point	55°
Degree of dryness on the thermometric scale .	15°
Degree of moisture on the hygrometric scale .	618
Elasticity of the vapour	·476 ins.
Weight of vapour in a cubic foot	5·175 grs.

The state of the atmosphere, assumed above, would constitute fine weather; and one of two things, or a modification of both, must happen, before any precipitation of water could take place: either the temperature of the air must fall below 55°; or the quantity of vapour must increase to 8·392 grains in the cubic foot, the maximum quantity which could exist at 70°; or the point of condensation may become intermediate, by a corresponding rise and fall of the two.

In the first case, the precipitation would probably be only slight and transitory, such as mist or fog: in the second case, it would assume the form of hard rain and storms: while, in the third, some conjecture might be formed of its probable duration and quantity, according as one or other of its causes prevailed.

But the hygrometer can be made to measure not only the quantity and force of vapour existing at any time in the air, but may be applied at the same time to indicate the force and quantity of evaporation.

Dr. Dalton, in the course of that important train of investigation to which I have before had occasion to refer, ascertained that the quantity of water, evaporated in a given time, bore an exact proportion to the force of vapour at the same temperature. The atmosphere obstructs its diffusion, which would otherwise be instantaneous, as *in vacuo;* but this obstruction is overcome with a celerity proportioned to the force of the vapour. The retardation, however, does not arise from the weight of the air, for that would prevent any vapour from arising under 212°; but, as Dr. Dalton observes, is caused by the *vis inertiæ* of the particles of air, and is similar to that which a stream of water meets with in descending amongst pebbles. In ascertaining this point at ordinary atmospheric temperatures, regard must be had to the force of vapour already existing in the air. For instance, if water of 57° were the subject, the force of vapour of that temperature is $\frac{1}{60}$th of the force at 212°; and one might expect the quantity of evaporation to be $\frac{1}{60}$th also; but if it should happen that an aqueous atmosphere to that amount does already exist, the evaporation, instead of being $\frac{1}{60}$th of that from boiling water, would be nothing at all. On the other hand, if the aqueous atmosphere were less than that, suppose half of it, then the effective evaporating force would be $\frac{1}{120}$th of that from boiling water; in short, the evaporating force must be universally equal to that of the temperature of the water diminished by that already existing in the atmosphere. But the air, by its mechanical action, has another influence upon the rate of

evaporation. When calm and still, it merely obstructs the process; but when in motion, it increases its effect in direct proportion to its velocity, by removing the vapour as it forms. Dr. Dalton fixes the extremes that are likely to occur in ordinary circumstances at 120 and 189 grains per minute, from a vessel of six inches diameter, at a temperature of 212°. Upon these *data* the following Table was constructed, in which Dr. Dalton's results have been accommodated to the progression of elasticity adopted in Table I., from Dr. Ure, by the slight alteration of moving the temperature back two degrees.

Table II. *Showing the Force of Vapour, and the full evaporating Force of every Degree of Temperature, from* 18° *to* 85°; *expressed in Grains of Water that would be raised per Minute from a Vessel of Six Inches in Diameter, supposing there were no Vapour already in the Atmosphere.*

Temp.	Force of Vapour.	Evap. Force in grs.			Temp.	Force of Vapour.	Evap. Force in grs.		
212°	30·000	120 gr.	154 gr.	189 gr.	212°	30·000	120 gr.	154 gr.	189 gr.
18	·131	0·52	0·67	0·82	52	·428	1·71	2·20	2·69
19	·135	0·54	0·69	0·85	53	·444	1·77	2·28	2·78
20	·140	0·56	0·71	0 88	54	·460	1·83	2·35	2·88
21	·146	0·58	0·73	0·91	55	·476	1·90	2·43	2·98
22	·152	0·60	0·77	0·94	56	·492	1·96	2·52	3·08
23	·158	0·62	0·79	0·97	57	·508	2·03	2·61	3·19
24	·164	0·65	0·82	1·02	58	·526	2·10	2·70	3·30
25	·170	0·67	0·86	1·05	59	·543	2·17	2·79	3·41
26	·176	0·70	0·90	1·10	60	·560	2·24	2·88	3·52
27	·182	0·72	0·93	1·13	61	·577	2·31	2·98	3·63
28	·188	0·74	0·95	1·17	62	·594	2·39	3·07	3·76
29	·194	0·77	0·99	1·21	63	·615	2·46	3·16	3·87
30	·200	0·80	1·03	1·26	64	·636	2·54	3·27	3·99
31	·208	0·83	1·07	1·30	65	·657	2·62	3·37	4·12
32	·216	0·86	1·11	1 35	66	·678	2·70	3·47	4·24
33	·224	0·90	1·14	1·39	67	·699	2·79	3·59	4·38
34	·232	0·92	1·18	1·45	68	·722	2·88	3·70	4·53
35	·240	0·95	1·22	1·49	69	·745	2·98	3·83	4·68
36	·248	0·98	1·26	1·54	70	·770	3·08	3·96	4·84
37	·256	1·02	1·31	1·60	71	·796	3·18	4·09	5·00
38	·264	1·05	1·35	1·65	72	·822	3·29	4·23	5·17
39	·272	1·09	1·40	1·71	73	·849	3·40	4·37	5·34
40	·280	1·13	1·45	1·78	74	·877	3·52	4·52	5·53
41	·292	1·18	1·51	1·85	75	·906	3·65	4·68	5·72
42	·304	1·22	1·57	1·92	76	·936	3·76	4·83	5·91
43	·316	1·26	1·62	1·99	77	·966	3·88	4·99	6·10
44	·328	1·31	1·68	2·06	78	·997	4·00	5·14	6·29
45	·340	1·36	1·75	2·13	79	1·028	4·16	5·35	6·54
46	·352	1·40	1·80	2·20	80	1·060	4·28	5·50	6·73
47	·364	1·45	1·86	2·28	81	1·093	4·40	5·66	6·91
48	·376	1·50	1·92	2·36	82	1·127	4·56	5·86	7·17
49	·388	1·55	1·99	2·44	83	1·162	4·68	6·07	7·46
50	·400	1·60	2·06	2·51	84	1·198	4·80	6·28	7·75
51	·414	1·66	2·13	2·61	85	1·235	4·92	6·49	8·04

The first column contains the degrees of temperature; the second, the corresponding force of vapour; the third, the amount of evaporation, per minute from a vessel of six inches diameter in calm weather; the fourth, the amount in a moderate breeze; and the fifth, in a high wind.

The use of this Table, as applied to the hygrometer, is this:—Let it be required to know the force of evaporation at the existing state of the atmosphere: find the point of condensation by the instrument, as before directed; subtract the grains opposite that temperature, either in the third, fourth, or fifth columns, according to the state of the wind, from the grains opposite to the temperature of the air in the same column, and the remainder will be the quantity evaporated in a minute from a vessel of six inches diameter, under the given circumstances. For example:—Let the point of condensation be 55°, the temperature of the air 70°, with a moderate breeze. The number opposite to 55° in the fourth column is 2·43, and that opposite to 70° is 3·96: the difference, 1·53 grain, is the evaporation per minute.

But it is, perhaps, simpler and more convenient, in many cases, to estimate the depth of the water evaporated in a day; and Dr. Young has shown how this may be done, from Dr. Dalton's *data*. It happens that the column of mercury equivalent to the elasticity of the vapour, expresses, accurately enough, the mean evaporation in 24 hours. Dr. Dalton's experiment gives 45 grains per minute, at the temperature of 212°, from a disc of 3¼ inches. Now $45 \times 60 \times 24 = 64{,}800$ grains,

or 256·6 cubic inches, which would make a cylinder 30·9 inches in height, on a base $3\frac{1}{4}$ inches in diameter; and this differs only $\frac{1}{33}$ from the height of the column of mercury. We may, therefore, assume that the mean daily evaporation is equal to the tabular number expressing the elasticity of the vapour; sometimes exceeding it, or falling short of it about one-fourth; and we may readily allow for the effect of the moisture of the atmosphere, by deducting the number corresponding to the temperature of deposition. Thus, supposing the mean temperature of 24 hours to be 60°, and that of the dew-point 50, the evaporation will be equal to $\cdot 560 - \cdot 400 = \cdot 160$ inch.

It is evident that these estimates can be but mere approximations; for till we can obtain some accurate measure of the velocity of the wind, they must be liable to great uncertainty. They are, however, as much to be relied upon as the registers of the evaporating gauge in common use, whose only proper application can be to furnish a rough estimate of the state of atmospheric saturation, and the point of deposition. The notion that these afford the absolute measure of the quantity of water raised into the air is absurd, for the instrument can only give the amount of evaporation from the shallow body of water in the place where it has been fixed. The conditions which modify the process vary almost *ad infinitum*. They vary on the land and on the water; they vary in sun-shine and in the shade; they vary as land is more or less clothed with vegetation, or as water is more or less deep. The evaporating gauge, so far from representing the cir-

cumstance of those bodies which yield the great body of vapour on the earth's surface, probably does not correspond, in all essential particulars, with a dozen puddles in the course of the year; and the pains which are often taken to make the results tally with those of the rain-gauge, or to compare the two, are wholly misdirected. The results of the hygrometer, as applied above, accommodate themselves more easily to the ever-varying conditions of the problem; and from these we can infer the effect of each combination of circumstances, and the capacity of the air for moisture modified by the velocity of the winds.

§ 3. APPLICATION TO BAROMETRIC MEASUREMENTS.

The next application of the hygrometer is not of inferior importance to any of those which we have been considering: I allude to its application to the correction of barometrical measurements. Ever since the celebrated and important experiment of Torricelli, the attention of some of the greatest philosophers has been drawn in succession to the interesting problem of the mensuration of heights by means of the barometer. The most laborious experiments have been undertaken for the improvement of the practical part of the operation, and the utmost refinements of mathematical calculation have been employed in the perfecting of its theory. To the former, M. de Luc, General Roy, and Sir George Shuckburgh, have pre-eminently contributed; while the powerful minds of Halley, Newton, Playfair, and Laplace, have been

applied to the latter. But one *desideratum* in Physics has stopped the progress of each at nearly the same point; a desideratum which all have felt, and all in succession have pointed out. I allude to the deficiency of means to measure the quantity and effects of aqueous vapour in the atmosphere. The relation of the density and elasticity of the air, the effects of heat upon the relative weights of mercury and air, the diminution of gravity in ascending from the surface of the earth, its variation in different latitudes, and the disturbance of centrifugal force, have been appreciated and allowed for; but all the corrections, excepting the two first, are exceeded in value by that which has hitherto been only the subject of conjecture; namely the correction for moisture. Some of the latter calculations have, indeed, assumed an appearance of considerable accuracy; but while the more important problem remains unsolved, such appearance is only illusory; and it may even be doubted whether the state of physical science is ever likely to be such as to render the introduction of the refinements which they exhibit practically advantageous. The importance, however, of the problem, the solution of which I am now about to attempt, has, on the contrary, been universally admitted.

M. de Luc, in his valuable and laborious *Researches upon the Modifications of the Atmosphere*, thus adverts to the knowledge of the effects of vapour in the air which it is necessary to obtain in order to perfect the mensuration of heights by means of the barometer.

"Voilà donc un nouveau champ ouvert aux expé-

riences. Il s'agit de détérminer quel changement on doit faire à la hauteur trouvée par les logarithmes, quand l'air est plus ou moins chargé de vapeurs qu'un certain point fixe et de vapeurs échauffées plus ou moins qu'un certain degré. Il me semble que pour découvrir cette loi, il faudroit pouvoir joindre l'observation d'un hygromètre comparable à celle du baromètre et thermomètre car le point essentiel consiste à connoître s'il y a des vapeurs dans la colonne d'air qui est interceptée par les deux stations et quelle est leur quantité; puisque, si les vapeurs qui font baisser le baromètre sont plus élevées que cette colònne, elles ne changent point la loi générale qui sert de fondement au calcul.

"Lorsqu'on aura obtenu ce premier point, il sera facile de connoître par l'expérience. 1°, Si les vapeurs influent de la même manière quelque soit la densité de l'air produite par la pression supérieure, et par consequent, quelque soit la hauteur du mercure dans la baromètre. 2°, Quel rapport il y a entre la quantité des vapéurs exprimée par les degrés de l'hygromètre, et la diminution d'elasticité de l'air par une température donnée; ou plus directement, quelle partie proportionelle il faut déduire de la hauteur trouvé par le calcul, ou ajouter à cette hauteur, pour chaque degré de l'hygromètre quand l'air est à cette température. 3°, Enfin, quelle modification doit éprouver ce rapport lorsque la chaleur est plus ou moins grand que le point fixe, auquel la force expansive des vapeurs est égale à celle de l'air.

"Je conviens que tout cela présente bien des

soins et des peines au premier coup-d'œil, mais j'ai éprouvé plus d'une fois que les difficultés connues s'applanissent beaucoup quand on les affronte avec courage*."

General Roy, in commenting upon his experiments upon the different expansions of dry and moist air for the elucidation of the same subject, says:—

"I am aware it will be alleged, that the proportion of moisture admitted into the manometer in these experiments, is greater than what can ever take place in nature; and, therefore, in order to be able to judge of the degrees of expansion the medium suffers in its more or less dense, and more or less moist, states, that not only air near the surface of the earth, but likewise that found at the top of some very high mountains should have been made use of. I grant all this; but, on the other hand, it must be remembered, that those experiments are very recently finished; that a good hygrometer, (if such can ever be obtained,) a great deal of leisure time, and the vicinity of high mountains, were all necessary for the carrying of such a scheme into execution. It is for these reasons, and in hopes that other people will sooner or later investigate this matter still further, not only by experiments made on the expansion of air taken at different heights above the level of the sea in middle latitudes, but likewise, on that appertaining to the humid and dry regions of the atmosphere towards the equator and poles, that I have been induced to hasten the commu-

* Tome iii. p. 288.

nication of this paper. In the mean time, having proved beyond the possibility of a doubt, that a wonderful difference doth exist between the elastic force of dry and moist air, I may be allowed hereafter to reason by analogy on the probable effects this will produce in measuring heights by the barometer*."

M. Laplace, who has applied the prodigious powers of his science to the perfecting of the barometric *formula*, and has availed himself of all the accuracy of the modern method of experiment, was forced to leave the hygrometric state of the air in the catalogue of inevitable errors, contenting himself with an approximate correction:—

"Les corrections," says he, "relative à la latitude, et à la variation de la pesanteur, sont très-petites, mais commes elles sont certaines il est utile de les employer pour ne laisser subsister dans le calcul que les erreurs inévitables des observations, et celles qui résultent des attractions inconnues des montagnes, *de l'état hygrométrique de l'air, auquel il serait nécessaire d'avoir égard*, et enfin de la hypothèse adoptée sur la loi de la diminution de la chaleur. On tiendrait compte en partie, de l'état hygrométrique de l'air en augmentant un peu le coefficient 0·00375 de $\frac{t+t'}{2}$ dans la formule précédente; car la vapeur aqueuse est plus légère que l'air, et l'accroissement du température en accroit la quantité toutes choses égales d'ailleurs†."

* *Phil. Trans.*, vol. lxvii. p. 714.

† *Mécanique Céleste*, tom. iv. p. 292.

Professor Playfair, in an elaborate paper upon the same subject, published in the *Philosophical Transactions of Edinburgh*, (vol. i., 1778), thus enforces the same argument: "There is another cause of error, which, had the effects of it been sufficiently known, ought, no doubt, to have entered into this investigation. Moisture, when chemically united to air, or dissolved in it, so as to form part of the same homogeneous and invisible fluid, appears to have a powerful effect to increase the elasticity of the air and its expansion, for every additional degree of heat which it receives. Though the judicious and accurate experiments of General Roy have ascertained this effect of humidity, and have even gone far to determine the law of its operation; yet, for want of a measure of the quantity of it contained at any given time in the air, it is impossible to make any application of this knowledge to the object under our consideration."

Lastly, Professor Leslie, in an article upon barometrical measurements in the *Supplement to the Encyclopædia Britannica*, concludes his detail of corrections with the same acknowledgment. "The humidity of the air also materially affects its elasticity, and the hygrometer should therefore be conjoined with the thermometer in correcting barometrical observations. But nothing satisfactory has yet been done with regard to that subject. The ordinary hygrometers, or rather hygroscopes, are mere toys, and their application to science is altogether hypothetical."

Impressed with the importance of the object, so clearly pointed out by a succession of the most able

philosophers, I had no sooner succeeded in constructing an instrument which, upon unerring principles, would show the quantity of vapour contained at any given time in the air, than I turned my attention to render it available to the desired purpose; and I shall now endeavour to explain a method of observation and calculation which, I trust, will be found to solve this important problem with sufficient precision.

The most simple way of considering the subject, in a general point of view, appears to me to be that which was, I believe, first suggested by Sir George Shuckburgh*, namely, to make a comparison of the specific gravities of mercury and air at a fixed temperature, and under a given pressure, the foundation of the operation. In this manner we calculate the height of a column of air, compared with any given column of mercury of equal base, supposing it of equal density throughout. The calculation of the gradual diminution of density which takes place for equal ascents in the atmosphere, according to a geometrical progression, is made in the usual way, by means of logarithms. This latter calculation may be deemed invariable under all circumstances; the former includes all the adventitious circumstances, and all the effects of disturbing causes.

The well-known accuracy of MM. Biot and Arago, assisted by the nicety of modern instruments, has determined the relative specific gravities of dry air and mercury at a temperature of 32°, and under a

* *Phil. Trans.*, vol. lxvii. p. 556.

pressure of 30·00 inches, to be as 1 to 10,435. The height of a column of air, therefore, of equal density throughout, which would balance a column of mercury of 30 inches, under these conditions, would be very nearly 26,090 feet.

Now, these proportions may be disturbed in two ways by the operation of heat. In the first place, its expansive power, acting upon the mercury, may dilate or contract its particles; so that a column of 30 inches, being more or less dense, will require an equipoise of greater or less length, according as its temperature is below or above the standard at 32°. This effect has been most minutely appreciated, and its correction is applied with the utmost ease and precision. In the second place, the power of heat, acting upon the air, occasions a much more considerable dilatation or contraction of its parts, and gives rise to much greater differences in the height of the equiponderant column. The expansion of air has been determined, as we have already stated, by the experiments of M. Gay Lussac, and from them we infer, that it increases or diminishes $\frac{1}{480}$th part for every addition or subtraction of 1° of heat. In this situation, therefore, the operation stands: the column of mercury, which is the measure applied, is rendered an invariable standard of comparison, by being brought by an easy calculation to a known density; and the altitude measured is in proportion to the specific gravity of the air.

But heat is not the only agent which alters the specific gravity of the air; the admixture of aqueous

vapour, it is well known, produces very important changes in its density. It did not, as I have shown, escape the observation of General Roy, that air, in contact with water, expanded much more than dry air; and, from well-conducted experiments, he ascertained that the expansion was greater for equal increments as the temperature rose. From the mean results which he obtained, the following increasing rates of expansion were derived:—1000 parts of air, in contact with water, and under a pressure of 32·18 inches, expanded for each degree

From 0 to 32	....	2·22799
„ 32 „ 52	....	2·58800
„ 52 „ 72	....	2·97228
„ 72 „ 92	....	3·63194
„ 92 „ 112	....	4·91072
„ 112 „ 132	....	6·86550
„ 132 „ 152	....	9·89494
„ 152 „ 172	....	12·04087
„ 172 „ 192	....	17·88344
„ 192 „ 212	....	19·22470

I am indebted to M. Gay Lussac for the following clear method of explaining the expansion of a dry gas by the admission of aqueous vapour and for the formula by which its effects may be calculated:—

Let us suppose that the gas in contact with the water in an inextensible vessel, has an elastic force equal to $p + f$ (p being the pressure of the atmosphere and f the force of the vapour). If the vessel should now become extensible, it would dilate until the interior pressure became equal to the exterior; so that as f is constant the gas will expand until its elasticity

become equal to $p-f$, and the volumes being in inverse proportion to the compression, v, the volume of air before its mixture with the vapour, is to V, its volume after mixture, as $p-f:p$; that is to say

$$v : V :: p-f : p;$$

$$\text{so that } V = v\left(\frac{p}{p-f}\right) \quad \text{or}$$

$$\text{if } v = 1, \quad V = \frac{p}{p-f}$$

Thus if it be required to know the expansion which would take place in air, in contact with water, by a rise from 0° to 32°. The force of vapour at the freezing point, according to Dr. Ure's table, is 0·216 inches; therefore

$$30{\cdot}000 : 30{\cdot}216 :: 1{\cdot}00000 : 1{\cdot}00720$$

This is the expansion which would arise from vapour only: to this we must add the expansion which would take place from the addition of heat. Now ·00223 (the expansion per degree for the bulk at 0°,) × 32 = ·07802; which, added to 1·00720, makes the total expansion 1·08522.

But the expansion which vapour causes in air, is not precisely similar to that occasioned by heat; for while it dilates its parts, it adds its own weight to the mixture. Let it be required to know the specific gravity of air at 32°, saturated with vapour, compared with dry air, at the same temperature. Call the latter 1·00000: the quantity of expansion will be ·00720; which, deducted from 1·00000, leaves ·99280. Now the weight of a cubic foot of air, under the conditions above named, is 558·131 grains; and the weight of

a cubic foot of vapour at 32°, is 2·539 grains; which, the former being 1·00000, will be nearly ·00455; and which, added to the ·99280 before obtained, will give ·99735 for the specific gravity sought*.

Upon this principle I have constructed the following table, by means of which the specific gravity of any mixture of atmospheric air and aqueous vapour from 0° to 90°, may readily be found with sufficient precision. I have made air, under a pressure of 30 inches of mercury and at the temperature of 32°, the standard of comparison. The first column contains the degrees of Fahrenheit's thermometer; the second shows the quantity due to each degree of heat, to be subtracted, or added, according as the temperature is above or below the standard; the third exhibits the expansion of volume occasioned by vapour of the respective degrees of elasticity appropriate to the several degrees of heat, and is always to be subtracted; the fourth is the correction to be applied for the weight of the vapour, and is constantly to be added; and the fifth is the correct specific gravity, supposing the air saturated with moisture at the given temperature.

* The Astronomer-Royal, in the *Greenwich Observations*, has given a table of the weight of a cubic foot of dry air at all temperatures between 0° and 90°, under mean pressure, making from a mean of experiments, the weight at 32°, 563·0 grains.

TABLE III. *For finding the Specific Gravity of any Mixture of Air and Aqueous Vapour, at Mean Pressure, from 0° to 90°.—Dry Air at 32° Temperature and 30 Inches' Pressure, being* = 1·0000.

Temp.	Alteration of Volume from Heat.	Alteration of Volume from Vapour.	Increase of Density from Weight of Vapour.	Correct Specific Gravity of Saturated Air.
0°	−·06666	+·00227	+·00153	1·0703
1	−·06458	+·00237	+·00159	1·0679
2	−·06249	+·00247	+·00166	1·0655
3	−·06041	+·00257	+·00172	1·0631
4	−·05833	+·00267	+·00179	1·0607
5	−·05624	+·00277	+·00185	1·0583
6	−·05416	+·00287	+·00191	1·0559
7	−·05208	+·00298	+·00197	1·0536
8	−·04999	+·00308	+·00204	1·0512
9	−·04791	+·00318	+·00210	1·0489
10	−·04583	+·00328	+·00216	1·0466
11	−·04374	+·00344	+·00224	1·0442
12	−·04166	+·00358	+·00234	1·0419
13	−·03958	+·00372	+·00243	1·0396
14	−·03749	+·00385	+·00251	1·0373
15	−·03541	+·00398	+·00260	1·0350
16	−·03333	+·00412	+.00268	1·0827
17	−·03124	+·00425	+·00276	1·0304
18	−·02916	+·00439	+·00284	1·0282
19	−·0.708	+·00452	+·00292	1·0260
20	−·02500	+·00469	+·00302	1·0239
21	−·02291	+·00489	+·00314	1·0215
22	−·02083	+·00509	+·00327	1·0194
23	−·01874	+·00529	+·00339	1·0171
24	−·01666	+·00549	+·00351	1·0148
25	−·01458	+·00570	+·00363	1·0125
26	−·01249	+·00590	+·00375	1·0104
27	−·01041	+·00610	+·00387	1·0082
28	−·00833	+·00631	+·00399	1·0061
29	−·00624	+·00651	+·00411	1·0041
30	−·00416	+·00671	+·00423	1·0017
31	−·00208	+·00698	+·00439	·9995
32	·00000	+·00725	+·00454	·9973
33	+·00208	+·00752	+·00471	·9952

TABLE III. *continued.*

Temp.	Alteration of Volume from Heat.	Alteration of Volume from Vapour.	Increase of Density from Weight of Vapour.	Correct Specific Gravity of Saturated Air.
34°	+·00416	+·00779	+·00486	·9927
35	+·00624	+·00806	+·00502	·9909
36	+·00833	+·00834	+·00518	·9887
37	+·01041	+·00864	+·00533	·9867
38	+·01249	+·00889	+·00549	·9846
39	+·01458	+·00915	+·00564	·9824
40	+·01666	+·00942	+·00580	·9804
41	+·01874	+·00983	+·00604	·9783
42	+·02083	+·01024	+·00627	·9761
43	+·02291	+·01064	+·00650	·9741
44	+·02499	+·01105	+·00674	·9720
45	+·02708	+·01146	+·00697	·9699
46	+·02916	+·01187	+·00720	·9679
47	+·03124	+·01228	+·00743	·9658
48	+·03333	+·01269	+·00766	·9636
49	+·03541	+·01310	+·00789	·9616
50	+·03749	+·01351	+·00803	·9596
51	+·03958	+·01399	+·00839	·9575
52	+·04166	+·01447	+·00864	·9555
53	+·04374	+·01502	+·00896	·9535
54	+·04583	+·01557	+·00926	·9514
55	+·04791	+·01612	+·00957	·9494
56	+·04999	+·01667	+·00987	·9474
57	+·05208	+·01723	+·01017	·9453
58	+·05416	+·01784	+·01051	·9433
59	+·05624	+·01843	+·01083	·9414
60	+·05833	+·01902	+·01114	·9394
61	+·06041	+·01961	+·01146	·9374
62	+·06249	+·02020	+·01178	·9354
63	+·06458	+·02093	+·01217	·9334
64	+·06666	+·02166	+·01256	·9314
65	+·06874	+·02239	+·01295	·9295
66	+·07083	+·02312	+·01334	·9275
67	+·07291	+·02386	+·01372	·9255
68	+·07499	+·02466	+·01415	·9235
69	+·07708	+·02546	+·01457	·9216
70	+·07916	+·02634	+·01503	·9196
71	+·08124	+·02725	+·01551	·9177

TABLE III. *continued.*

Temp.	Alteration of Volume from Heat.	Alteration of Volume from Vapour.	Increase of Density from Weight of Vapour.	Correct Specific Gravity of Saturated Air.
72°	+·08333	+·02817	+·01598	·9157
73	+·08541	+·02912	+·01648	·9137
74	+·08749	+·03011	+·01699	·9117
75	+·08958	+·03114	+·01752	·9098
76	+·09166	+·03221	+·01810	·9079
77	+·09374	+·03327	+·01861	·9059
78	+·09583	+·03438	+·01916	·9039
79	+·09791	+·03548	+·01973	·9020
80	+·09999	+·03663	+·02030	·9001
81	+·10208	+·03781	+·02090	·8982
82	+·10416	+·03903	+·02150	·8962
83	+·10624	+ 04029	+·02213	·8943
84	+·10833	+·04159	+·02277	·8924
85	+·11041	+·04293	+·02343	·8905
86	+·11249	+·04431	+·02411	·8885
87	+·11458	+·04573	+ 02486	·8867
88	+·11666	+·04716	+·02549	·8847
89	+·11874	+·04858	+·02618	·8828
90	+·12083	+·05005	+·02688	·8809

To find the specific gravity of any mixture of air and aqueous vapour by means of this Table, we must proceed as follows:—Note the temperature and the point of condensation, by the hygrometer; if they coincide, that is to say, if the air be in a state of saturation, we shall find the specific gravity required in the fifth column, opposite to the proper degree of heat in the first column. If the point of condensation be below the temperature, we must look for the correction to be applied separately for the heat in the second column. The quantity to be subtracted, for the vapour of the given degree, must be sought for

in the third column, and must be applied *minus* the quantity due to its weight, which stands beside it in the fourth.

For example:—If we wish to know the specific gravity of a mixture of air and vapour, of the temperature of 60°, and of which the dew-point is 40°, we find in the second column, opposite to 60°, the number ·05833; which, deducted from 1·00000, leaves ·94167. In the third column, opposite to 40°, we have ·00942; and beside it in the fourth, ·00580. Now ·00942 – ·00580 = ·00362; which, subtracted from ·94167, leaves ·93805 as the number sought.

The application of this Table to barometrical mensurations is sufficiently simple. For this purpose, with the usual operations at the upper and lower stations, must be combined simultaneous observations of the dew-point, by means of the hygrometer; and the approximate height, deduced in the common way, may, at once, be corrected for temperature and moisture, by the specific gravity of the air so obtained. As the specific gravity of the air at the time of the experiment is to 1·00000, the standard, so will the approximate height be to the real height.

General Roy, from his own experiments, as well as from a careful review of those of De Luc, made the medium expansion of air for 1° = ·00245; and Sir George Shuckburgh assigned ·00243 as the mean. These estimates, derived from barometrical experiments, made at different temperatures, and compared with known heights, must have included also the expansion due to the mean quantity of vapour; and

upon reference to the last Table, it will be found that the medium of the two combined effects is exactly ·00244 for every degree of temperature; for ·85839 deducted from 1·00000, leaves 0·14161, which, divided by 58, the total number of degrees from 32° to 90°, gives ·00244.

General Roy, again, has fixed the point of temperature at which the specific gravity of mercury to the atmosphere is 10,435, at 32°; the average of his experiments, however, making it a little lower. Sir George Shuckburgh places it at 31¼ It is worthy of remark, that the point which approaches the nearest, by the Table, to exact coincidence, is 31°; for at 32° the effects of temperature being null, a fall of one degree is necessary to neutralize the expansion of the vapour.

I shall now suppose a case, in which all the proper observations have been made, for the purpose of showing more distinctly the manner in which I propose to apply the table of correction.

Barom. at lower station	29·528	Temp. of mercury	58°
upper ditto	28·161	. . Do. . .	51°
Deduct for temp. of	29·528		
mercury	·084		
	29·444	Logarithm	·4689378
Deduct for temp.	28·161		
mercury	·060		
	28·101	Logarithm	·4487063
		Approximate height in fathoms	202·315
			× 6
		Ditto ditto in feet .	1213·890

Temp. of air at lower station	55°	Dew-point	40°	
Ditto ditto upper ditto	$51\frac{1}{2}$	Ditto	38	
Mean . . .	$53\frac{1}{4}$			

Expansion of air at 53° per Table		·04374
Expansion for vapour at 40°	·00942	
at 38°	·00889	
Mean		·00915
Total expansion		·05289

105289 : 100000 : : 100000 : ·94976

Increase of density for vapour at 40° . .	·00580	
at 38° .	·00549	
Mean . . .		·00564
Correct specific gravity .		·95540

	S. G. of air.	Standard.		Approx. height		Correct height.
Then	·9554 :	10000	: :	1214	:	1270

Or the correction may at once be made upon the comparative sp. grav. of mercury and air, and the height of the homogeneous atmosphere.

	S. G. of air.	Standard.		S. G. of mercury.		
For	·9554 :	10000	: :	10435	:	10922

and $10922 \times 30 = 327660$ inches, or 27305 feet.

Correct height of the homogeneous atmosphere of the specific gravity found by the observations.

	Modulus of Logarithm.	Diff. of Logarithm.		Homogen. Atmosph.		Correct Height.
Then	·4342945 :	202315	: :	27305	:	1272.

Professor Playfair, in his elaborate Essay upon Barometrical Measurements, suggested* the idea of fixing two barometers, the one at the top, and the other at the bottom of a high tower or hill of moderate elevation; to be observed at the same instant,

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* *Works of* John Playfair, Esq., vol. iii. p. 85.

together with their corresponding thermometers, for the purpose of computing from the variation of the difference of their heights the quantity of moisture dissolved in the air. "The height at which the one barometer," he observes, "should be placed above the other, ought not to be so small that the unavoidable errors of observation (which may amount to five feet) may be considerable in respect of the whole; nor so great as to introduce error from other causes. It ought not, therefore, to be less than 100, nor much greater than 500 feet." He concludes,—"Nor can this application of the barometer fail of leading to some useful conclusion; for if, on trial, it shall be found that the operation of humidity in changing the specific gravity of the air is overruled or concealed by the action of more powerful causes, the discovery, even of this fact, will give a value to the observations."

This suggestion is no longer required for the purposes of hygrometry, as we have now the means of accurately appreciating the effects of moisture upon the air: but there is no doubt that it might be applied to the discovery of other atmospheric influences. For this purpose it is now particularly fitted, as the hygrometric correction may be independently applied with certainty; and any other disturbances are disengaged from this source of ambiguity.

I have long wished for an opportunity of making the attempt with all the requisite precautions; but, as it is one which requires patient and very careful cooperation, I have not been able to execute the details satisfactorily. The following experiments, however,

though necessarily deficient in precision, may not be without interest, and their results may possibly induce others to undertake an investigation which promises amply to repay a patient pursuit.

I have been extremely anxious to ascertain, in the first place, to what degree of precision it is possible to arrive in barometrical mensuration, in different states of the atmosphere, when the corrections for temperature and vapour have both been made; and I availed myself of a long residence in the neighbourhood of Box Hill, and Leith Hill, in Surrey, to decide the point, as far as these heights would permit me; and also to select a series of stations for further experiments. The great disadvantage that I had to contend with, consisted in the want of contemporaneous observations; in lieu of which I was obliged to substitute the mean of two observations, at the lower station, at setting out and returning. I shall here give the details of four measurements of Leith Hill, to show the degree of uncertainty which attaches to this method of proceeding. The heights of the barometer are corrected for all adventitious circumstances, every precaution was taken in observing them, and the instrument was one upon the accuracy of which I had reason confidently to rely.

The lower station was at the foot of Box Hill, about forty-five feet above the bed of the river Mole; and the upper station, the tower upon Leith Hill, about seven miles distant:—

Table IV. *Barometrical Measurements of Leith Hill.*

Date. 1822.	Barometer.		Temperature.		Results.		Observations.
	Lower Station.	Upper Station.	Air.	Dew-Point.	Height in Feet.	Weight of Col. of Dry Air.	
			°	°			
June 24	29·924	—	71	58	—	—	Very fine, with some heavy clouds and heat drops. Not clear.
return	29·926	—	74	60	—	—	
—	—	29·057	69	59	841	·944	
July 1	29·993	—	66	44	—		Very fine and clear.
return	29·995	—	66	47			
—	—	29·128	64	43	823	·933	
Aug. 12	29·748	—	65	64	—	—	Close and damp, with small rain.
return	29.729	—	68	62	—	—	
—	—	28·875	65	60	842	·936	
Dec. 30	29·787	—	29	15	—	—	Very fine and very cold.
return	29·750	—	29	15	—	—	
—	—	28·819	26	15	838	·940	
					836	·938	Means.

The differences from the mean, exhibited by this Table, must be acknowledged to be very small, being only 6 feet in 836 feet, or ·006 in. of mercury in the weight of the intercepted column of air, corrected for vapour and temperature.

The next series of experiments was made upon a less elevation, but one which offered the advantage of easier access, and a smaller interval between the observations. The lower station was the same as before, and the upper, a clump of trees upon Hedley Heath, which forms a very conspicuous landmark for a large extent of surrounding country. This height I divided into three stations, one above the other, for the purpose of ascertaining whether the parts of a

height, so measured in divisions, would correspond with the direct measurement at two observations; in what part the error, if any, was most likely to occur; and also the effect of difference of position with regard to the surrounding hills. The first station above the point of departure was in a deep ravine, below the military road which leads to the top of Box Hill. It is surrounded, except at a narrow entrance, by very steep hills, those on each side being about 200 feet high. It was selected for the purpose of ascertaining whether a difference in the velocity of the wind passing over such a hollow, would produce any difference in the pressure of the atmospheric column. The second station was on the top of Box Hill, almost perpendicularly above the point from whence I set out; and the third, the trees before described upon the edge of the hill, which is very steep, and forms part of the boundary of a valley which runs at right angles to the one which is overlooked by the second station. I shall not attempt to give the particulars of the observations, which would occupy too much space, but only the calculated results, and such circumstances as may be supposed to have had an influence in their production. Each height was calculated from the mean of two observations, one made in the ascent, and the other on the return. They are included in the following Table: —

TABLE V. *Barometrical Measurements of Hedley Heath, at different Stages of the Height.*

Height of Ravine above the first Station	Difference from Mean.	Height of Box Hill above the Ravine.	Difference from Mean.	Height of Hedley above Box Hill.	Difference from Mean.	Height of Box Hill by direct Observation.	Difference from Mean.	Height of Box Hill by two Stations.	Difference from Mean.	Height of Hedley by direct Observation.	Difference from Mean.	Height of Hedley by three Observations.	Difference from Mean.	Temp. Air.	Temp. Dew-Point.	OBSERVATIONS.
165	+ 7·5	261	− 6·8	159	+ 1·2	427	+ 2·4	426	+ 0·7	586	+ 3·9	585	+ 1·9	33°	29°	Wind little and very cold.
168	+10·5	272	+ 4·2	161	+ 3·2	441	+16·4	440	+16·7	600	+17·9	601	+18·9	69	60	Wind S. and very high.
148	− 9·5	268	+ 0·2	147	−10·8	416	− 8·6	416	− 9·3	563	−19·1	563	−20·1	63	60	Wind S.W. and calm.
150	− 7·5	270	+ 2·2	157	− 0·8	421	− 3·6	420	− 5·3	578	− 4·1	577	− 6·1	61	52	Wind W and little.
156	− 1·5	265	− 1·2	155	− 1·2	416	− 8·6	421	− 4·3	571	−11·1	576	− 7·1	66	52	Ditto ditto.
158	− 0·5	271	+ 3·2	168	+10·2	427	+ 2·4	429	+ 3·7	595	+12·9	597	+13·9	81	66	Wind brisk on the Hill, and very hot.
157·5	—	267·8	—	157·8	—	424·6	—	425·3	—	582·1	—	583·1	Means.			

Of these observations, the first series was made at a time when the atmosphere was in such a state, as to require the smallest possible correction for temperature and moisture; and it will be observed, that the calculation from them of the height of the highest station, scarcely differs from the mean, the error being less than 2 feet in 585. The height of the next lower station also corresponds very closely; but in the height of the first station, we have a difference of 7·5 feet in 157. This difference, most probably, attaches to the observation in the ravine: for, if it had been in the first observation, it would have been discoverable in all the results; whereas, omitting the second, all the rest are correct, and the third is deficient exactly the quantity which is in excess in the second.

The last series forms the proper contrast to this, as requiring almost the greatest possible correction for both temperature and moisture: and here we perceive that the first and second heights are very correct, but there is a large error in the third, amounting to 10 feet in 158. The height of Box Hill thus differs from the mean only 2·4 feet; while that of Hedley Heath differs 13 feet; the error must, consequently, be included in the last observation.

In the second series of observations we find an error of 18 feet in the total elevation; but by attending to the analysis, we cannot, as in the two last cases, trace it to any particular station; it is largest at the first, but goes on accumulating at all: during this series, the wind was extremely violent.

The third set of observations exhibits great errors

in deficiency in the first and last sections of the elevation, but none in the intermediate. The results of the fourth are all pretty accurate; and those of the fifth present the only instance of any considerable difference between the measurement at one operation, and the measurement in parts.

The result of all the observations taken together prove, *that the intermediate station* was very considerably less liable to error than either of the extremes, and strongly suggests the following query:—Whether local currents of air, and those deflections of the wind, which are caused by the different directions of different valleys, may not produce various partial adjustments of density, which may have an influence upon barometrical mensuration?

The measurement of a height in divisions, does not appear, by this analysis, to be liable to any objection; and it possesses this great advantage, when the altitude is very considerable, viz., that we can make a much nearer approximation thereby, to the real specific gravity of the intercepted column of air, than by two observations only. This remark is applicable to the correction for temperature, but much more so to that for moisture; for, as we have seen in the previous investigation, the quantity of vapour does not decrease gradually, like the heat, with the elevation, but continues of nearly equal elasticity to a certain height, and then suddenly decreases considerably. The mean, therefore, of two observations, taken at the bottom of a mountain and at the top, might be very far indeed removed from the real state of the aërial column; and the more we multiply observations of the

dew-point, the more we diminish the chances of error from this source.

The last set of experiments includes a series of forty-five observations upon one height, under every possible variation of the atmosphere. The station was that upon Box Hill, which formed the second stage of the previous set. The results I shall divide into different classes, to ascertain the influence of different circumstances, and I shall express them by the length of the column of mercury, which would be the equipoise of the intercepted column of air, supposing it corrected for temperature and moisture. The mean result of all the observations is ·4848 inch.

The following Table includes the eleven observations, in which both corrections were at the greatest amount.

TABLE VI. *Barometrical Measurement of Box Hill, in very hot weather.*

Length of Column.	Temperature.		Dryness.
	Air.	Dew-Point.	
·486	81°	66°	15°
·485	68	59	9
·494	68	60	8
·470	67	61	6
·472	67	64	3
·495	66	56	10
·499	65	55	10
·495	65	57	8
·493	65	60	5
·479	65	59	6
·470	65	52	13
·4852 Mean.			

The average scarcely differs from the general mean. Seven observations in cold weather, in which the required corrections were very small, and mostly on the contrary side, are included in the following Table:

TABLE VII. *Barometrical Measurement of Box Hill, in very cold weather.*

Length of Column.	Temperature.		Dryness.
	Air.	Dew-Point.	
Inch.	°	°	°
·492	31	29	2
·494	34	30	4
·487	30	23	7
·486	29	28	1
·490	32	31	1
·474	27	25	2
·467	32	30	2
·4842 Mean.			

The average of these, again, only differs ·0006 inch from the same standard. These experiments may, therefore, be regarded as decisive of the adequacy of the corrections for temperature and vapour.

TABLE VIII. *Barometrical Measurement of Box Hill, with the Moon upon the Meridian.*

Length of Column.
·482
·483
·469
·474
·479
·486
·480
·470
·4778 Mean.

The preceding eight results were calculated from observations when the moon was nearly upon the meridian.

Here we have a small but decided difference, sufficient to strengthen the query already suggested in the first Essay. Does not the position of the moon influence, in some degree, the results of barometrical mensurations? The difference, ·007 inch, is in deficiency, and agrees, so far, with the anticipation of the effect.

The position of the sun may, also, be expected to have an influence upon the elastic fluids of the atmosphere, independent of its heating power; to determine which, the following observations at noon were extracted:—

TABLE IX. *Barometrical Measurement of Box Hill, with the Sun upon the Meridian.*

Length of Column.
·473
·470
·495
·475
·465
·476
·470
·486
·494
·474
·4778 Mean.

The difference is the same as in the last Table, and points to the same kind of planetary influence.

It is sufficient to justify the query—Does not the position of the sun affect the results of barometrical mensurations?

A third disturbing cause we cannot but look for in the operations of the electric fluid.

The following four observations were made when the atmosphere was highly charged, and just before the commencement of violent thunderstorms:—

TABLE X. *Barometrical Measurement of Box Hill during Thunderstorms.*

Length of Column.
·481
·485
·476
·465
·4767 Mean.

The experiments, it must be acknowledged, are not sufficient to establish the fact; but the mean difference, it will be observed, is more than a sixth of the total result, and strongly calls for further inquiry—Whether the electric state of the atmosphere does not affect the results of barometrical mensurations?

The following Table exhibits the barometrical results in the most opposite states of the wind, viz., when very high and when perfectly calm.

TABLE XI. *Barometrical Measurement of Box Hill in different States of the Wind.*

Length of Column.	
Wind high.	Calm.
·492	·475
·499	·465
·495	·476
·470	·470
·494	·472
·4900	·4716 Means.

The differences of +·0052 in wind, −·0132 in calm weather, induce me to conclude my queries by proposing the following question: What is the effect of wind upon barometrical mensurations? If I had had the means of prosecuting these inquiries in the complete manner which the nicety of the subject requires, I would not have suffered them to retain the form of crude speculations: but, under all circumstances, I am not without hopes that this premature publication may be useful. It may possibly illustrate Mr. Playfair's suggestion; it may indicate the objects which it is calculated to illustrate, and it exemplifies the method of proceeding.

§ 4. APPLICATION OF THE HYGROMETER TO CONFINED ATMOSPHERES.

The hygrometer may be applied also to artificial atmospheres, and experiments upon confined air. For this purpose a hole is drilled in the side of the glass-receiver of an air-pump, (Plate 1, fig. 2,) through which

the tube proceeding from the ball within it, containing the thermometer, is passed, and welded with the tube proceeding from the other ball on its exterior, by means of a lamp; the stem is secured in the side of the glass with cement, the ether boiled, and the capillary opening closed, as before directed. The external ball is then to be covered with muslin; by this arrangement the evaporation from the latter produces a corresponding degree of cold upon the internal ball, which will measure the quantity of vapour included, by the precipitation, which may readily be marked. In delicate experiments a lighted taper, in a glass lantern, placed behind the bulb of the instrument, renders the deposition more easily visible, and insures accuracy.

The hygrometric properties of any substance may thus be readily measured, by placing it under the receiver, and marking the absorption of the vapour.

The following may be taken as examples of the mode of experimenting.

Exp. 1.—With the thermometer at 60°, I found the point of condensation to be 50°: I then took a receiver, of the capacity of fifty-six cubic inches, fitted with a hygrometer, and ground to the plate of an air-pump. The condensation was produced very visibly under the glass at the same temperature. Now the quantity of vapour in a cubic foot of air, under the above conditions, was only 4·445 grains; therefore the quantity actually included in the receiver, could only be 0·144 grains; which will serve to prove the extreme delicacy of the instrument, as it distinctly indicated so small a quantity. The receiver was then,

without changing its contents, slid over a vessel containing water. In an hour and a half, the external temperature remaining the same, the precipitation took place at 57°. At the expiration of another hour and a half, the affusion of ether upon the exterior ball caused instantaneous condensation upon the interior one, showing that saturation, at the existing temperature, had taken place. The bell-glass was now slid from the water, and placed over a glass containing a few drops of sulphuric acid. After remaining a quarter of an hour in this situation, a depression of temperature of 30° produced no mist upon the instrument.

Exp. 2.—The receiver was placed upon the plate of the air-pump with some water under it; the air was then exhausted as perfectly as possible. The barometer stood at 29·79 inches, the thermometer at 62°; the gauge of the pump at 29·20; to the latter should be added the pressure of the included vapour at 62°=·59 inch, which would make the gauge and the barometer exactly correspond. When ether was dropped upon the exterior ball, precipitation was instantaneous. Air was now admitted gradually, till the gauge fell to 14 inches: the point of condensation was not altered, neither was it affected by restoring the equilibrium completely.

Exp. 3.—Temperature 64°; point of condensation 61°. The air in the receiver was rarefied till a copious cloud was formed; the gauge then stood at 8·1 inches, and the point of condensation had fallen to 54°. When the glass had risen to 60°, the air was suddenly restored, and a copious dew was formed upon it; the exhaustion

was next carried on, till the cloud which was formed had totally disappeared, and the gauge stood at 24·2 inches. No precipitation took place at a temperature of 34°; the air was gradually re-admitted, and the deposition took place with the hygrometer at 36°, and the gauge at 15 inches.

Exp. 4.—The receiver was filled with oxygen in contact with water, and afterwards with hydrogen; but the point of condensation was the same as when filled with common air, under the same circumstances. This result, as well as that of Experiment 2, fully coincides with Dr. Dalton's view of the theory of mixed elastic fluids, and proves, indeed, that the gases act as *vacua* with regard to vapour; and that, where they happen to be mixed together, they exist as independent atmospheres.

Exp. 5.—Having absorbed all the vapour contained in the receiver by means of sulphuric acid, I placed it over some spirits of wine; after remaining some time in this situation, a few drops of ether upon the hygrometer produced an instant precipitation. The experiment was also made with ether, in the place of the spirits of wine, with the same results.

Exp. 6.—The temperature of a room being 45°, I found the point of condensation in it to be 39°. A fire was lighted in it, the door and windows carefully shut, and no one was allowed to enter: the thermometer rose to 55°, but the point of condensation remained the same. A party of eight persons afterwards occupied the room for several hours, and the fire was kept up: the temperature increased to 58°, and the point of condensation rose to 52°.

Several alterations and supposed improvements of the dew-point hygrometer have been from time to time proposed and constructed, but experience has proved them to be deficient in accuracy, and they have not been adopted: it is therefore needless, at present, to enter upon any criticism upon them; and I shall proceed to record some examples of its application to confined atmospheres, and of the nature of the questions which it is capable of resolving. I shall not think it necessary to reprint the register of the meteorological observations of it, which I kept for three years, and published in the former editions of these Essays, nor the similar observations of my friends Colonel Sabine and Mr. Caldcleugh in tropical climates. These details are sufficiently upon record, and it may be permitted me, without encumbering my present work with a repetition of their details, now to make use of the general results to be derived from them, and the registers of Colonel Sykes, who extensively used the instrument in the East Indies.

I must not, however, omit the details of the observations made with it during Captain Parry's third voyage to the arctic regions. The few opportunities which will, probably, ever occur of repeating such observations under circumstances of so much interest render them particularly valuable, and they admirably illustrate the powers of the instrument in one extreme of climate. The performance of the experiments was rendered particularly difficult by the negligence of the instrument-maker who provided the supply of ether for the voyage. This was of such very bad quality as

scarcely to produce a depression of two or three degrees in the instrument; the deficiency was, however, ingeniously but laboriously supplied by a mixture of snow and salt or muriate of lime, applied to the covered ball.

"*H. M. S.* Hecla, *at Port Bowen;*
"*December*, 1824.

"Two experiments to ascertain if any moisture existed in the atmosphere, were made in the course of this month with Mr. Daniell's hygrometer; but none could be detected. On the 21st, the wind being light from the northward, with a perfectly clear sky, the instrument was exposed till both thermometers indicated the temperature of the atmosphere, which was $-30°$; and the freezing mixture (muriate of lime and snow) being then applied to the covered ball, the ether soon became frozen, and the thermometer immersed in it indicated $-46°$, without the slightest appearance of deposit. Mr. Foster repeated this experiment on the 25th, with very similar results, the temperature of the atmosphere being then $-25°\cdot5$ with calm and clear weather.

"*January*, 1825.—Mr. Daniell's hygrometer was twice tried during this month: on the 3rd, the temperature being $-30°$, and the instrument subjected to the same process as before, the ether froze without producing any deposit. The wind at this time was light from the eastward; the sky perfectly clear, except to the westward, where a dense haze indicated the vapour arising from open water in that direction.

"On the 24th, the temperature of the atmosphere

was $-35°$, the sky clear, with the exception of a few thin clouds near the horizon to the eastward, and the wind light from the north,—the experiment was repeated, and when the ether became frozen, the thermometer indicated $-50°$, without the slightest appearance of deposit on the coloured ball.

"*February*, 1825.—The hygrometer twice tried at the temperature of $-39°$ and $-28°{\cdot}5$, and the ether froze without any visible deposit.

"*April*, 1825.—Twice in this month Mr. Foster succeeded in obtaining a deposit on the coloured ball of Mr. Daniell's hygrometer. On the 21st, the temperature of the atmosphere being $+15°$, the sky partially clear, with large well-defined clouds to the westward, a broad white belt of frozen vapour appeared on the instrument, coincident with the surface of the ether, on the temperature being reduced to $-4°$. On the 25th, the temperature of the atmosphere being $+6°$, and the sky densely overcast, a similar deposit took place on the coloured ball on the ether being reduced to the temperature of $-1°{\cdot}5$.

"Mr. Daniell's hygrometer was tried on several occasions, in different parts of the ship. The following examples will show how great a degree of dryness was maintained below*:

"*January* 9. 11[h] 30[m] A.M.

Temp. of external air.		Middle of Lower Deck.	Dew-Point.	Remarks.
−22	....	+67·5	+53·5	All the people had been on the lower deck for an hour and a half previously, but were off the deck at the time.

* Parry's *Third Voyage*, p. 46.

"*April*, 11h 30m.

External air.			D. Point.	Remarks.
—20	Captain's cabin	+64	+48	A few people below, the copper boiling, and meat taking out.
	Gun-room .	+64·2	+50	
	Middle of lower deck . . .	+63·5	+55	
11th, 9·30 P.M.,	ditto,	+66	+55	The ship's company in bed.

§ 5. EVAPORATION.

The subject of evaporation has occupied, at various times, much of the attention of natural philosophers, and many accurate and interesting observations have been recorded of the formation and diffusion of elastic fluids, from various kinds of liquids. The circumstances, especially, attending the rise and precipitation of aqueous steam in the atmosphere, are acknowledged to be important in the highest degree, as upon their silent influence depends the adjustment of many of those important meteorological phenomena, with which is connected the welfare of the organized creation. The labours of De Luc, De Saussure, and particularly of Dr. Dalton, have thrown considerable light upon this never-ceasing process; but something appeared to be still wanting to complete the investigation, and I early thought that an accurate hygrometer might be employed to elucidate some of the points which appeared to be the most obscure. With this view, the experiments which I am about to detail were instituted.

It is a well-known fact that water, under all circumstances, is endued with the power of emitting vapour, of an elastic force proportioned to its temperature. It is also well understood, that the gaseous atmosphere of the earth, in some degree, opposes the

diffusion, and retards the formation of this vapour; not, as Dr. Dalton has shown, by its weight or pressure, but by its *vis inertiæ*. The amount of this opposition, and the progression by which it is connected with the varying circumstances of density and elasticity, have never yet been experimentally explained. The experiments of Professor Graham have determined that the diffusiveness of gas is inversely proportional to the square root of its density, and hence it follows that the diffusiveness of steam of equal elasticity is

$$\sqrt{0{\cdot}620} : 1 \text{ or } 1{\cdot}269$$
$$\text{for } 0{\cdot}788 : 1 :: 1 : 1{\cdot}269$$

It may facilitate the comprehension of the subject, to distinguish three cases with regard to the evaporating fluid: the first, when its temperature is such as to give rise to vapour equivalent in elasticity to the gaseous medium, and when it is said to boil; the second, when the temperature is above that of the surrounding air, but below the boiling point; and the third, when the temperature is below that of the atmosphere.

With regard to the first, all the phenomena have been accurately appreciated. The quantity evaporated from any surface, under any given pressure, is governed, in some measure, by the intensity of the source of heat, and is in no way affected by the motions of the aërial fluid. The elasticity of the vapour is exactly equivalent to that of the air, which yields *en masse* to its lightest impulse. When disengaged, it is immediately precipitated in the form of cloud, giving out

its latent heat to the ambient medium; and under that form is again exposed to the process of evaporation, according to the laws which regulate our third case. All the phenomena attending the process of boiling have been ably investigated by Gay-Lussac, Dalton, Ure, and Archdeacon Wollaston; but, as they have comparatively little connection with the atmospheric relations, which are the particular object of our present inquiries, I shall proceed to the second case of evaporation.

When the evaporating fluid is of a higher temperature than the surrounding air, but not so high as to emit vapour of elasticity equal to it, the exhalation is proportionate to the difference of temperature. The gaseous fluid, in contact with the surface, becomes lighter by the abstraction of portions of the excess of heat, and, rising up, carries with it, in its ascent, the entangled steam. (This, as in the former case, is precipitated, and, in the form of cloud, exposed to the third species of evaporation.) This process is not only proportioned to the difference of temperature, and the elasticity of the vapour, but is also governed by the motion of the air. A current of wind tends to keep up that inequality of heat upon which it depends, and prevents that equalization which would gradually take place in a stagnant air. Such is the evaporation which often takes place in this climate in autumn, from rivers, lakes, and seas, and which is indicated by the fogs and mists which hang over their surfaces.

It is, however, the third modification of circum-

stances, which is the most interesting in the point of view which I have suggested, and from which I have merely distinguished the preceding, to free the subject from ambiguity. When the temperature of water is below that of the atmosphere, it still exhales steam from its surface; but, in this case, the vapour, having neither the force necessary to displace the gaseous fluid, nor heat enough to cause a rapid circulation, which would raise it in its course, as in the preceding instance, (although the mixture of vapour and air is lighter than dry air, and would therefore have a tendency to rise,) is obliged to filter its way slowly through its interstices; and the nature of the resistance it meets with in this course is the first object of investigation.

The force of vapour, at different temperatures, has been determined, as we have seen, with great accuracy, and the amount of evaporation has been shown to be, *cæteris paribus*, always in direct proportion to this force. The quantity is also known to depend upon the atmospheric pressure, but I know of no experiments which establish the exact relation between the two powers.

This point I attempted to elucidate by inclosing in a glass receiver, upon the plate of an air-pump, a vessel with sulphuric acid, and another with water; by properly adjusting the surfaces of the two, it is easy to maintain, in the included atmosphere of permanently-elastic fluid, an atmosphere of vapour of any required force; or, in the usual mode of expressing the same fact, the air may be kept at any required degree

of dryness. The density of the air, in such an arrangement, may, of course, be varied and measured at pleasure. Now there are three methods of estimating the progress of evaporation in such an atmosphere: the first, and most direct, is by weighing to find the loss sustained by the water in a given time; the second, to measure, by a thermometer, the depression of temperature of an evaporating surface; and the third, to ascertain the dew-point, by means of the hygrometer.

Experiment 1.

The receiver which I made use of was of large capacity, and fitted with a hygrometer. I placed under it a flat glass dish, of 7½ inches diameter, the bottom of which I covered with strong sulphuric acid. The glass bell but just passed over it, so that the base of the included column of air rested everywhere upon the acid. In the centre of the dish, was a stand with glass feet, which supported a light glass vessel of 2·7 inches diameter, and 1·3 inches depth. Water to the depth of an inch was poured into the latter; the evaporating surface, therefore, stood just three inches above that of the acid. A very delicate thermometer rested in the water, upon the bottom of the glass, and another was suspended in the air. It may be necessary to observe, that the sides of the vessel were perpendicular to its bottom, which was perfectly flat. The height of the barometer was 29·6, and the temperature of the water 56°. In twenty minutes from

the beginning of the experiment, the hygrometer was examined, and no deposition of moisture was obtained at 26°.

This being the greatest degree of cold which could be conveniently produced by the affusion of ether, the experiment was repeated, with a contrivance which admitted of the application of a mixture of pounded ice and muriate of lime, to the exterior ball of the hygrometer. In this manner the interior ball was cooled to 0°, without the appearance of any dew. The temperature of the water and air was, in this instance, 58°, and the pressure of the atmosphere 30·5.

From this experiment it appears, that in the arrangement above described, the surface of water was not adequate to maintain an atmosphere of the small elasticity of ·068 inch; in other words, the degree of moisture in the interior of the receiver could not have exceeded 129, the point of saturation being reckoned 1000. How much it was less than this, or whether steam of any less degree of elasticity existed, the experiment, of course, did not determine. We may reckon, however, without any danger of error in our reasoning, that the sulphuric acid, under these circumstances, maintained the air in a state of almost perfect dryness.

Experiment 2.

The same trial was made with atmospheres variously rarefied by means of the pump. No deposition of moisture was, in any case, perceived, with the utmost depression of temperature which it was pos-

sible to produce; and the state of dryness was as great in the most highly attenuated air, as it was in the most dense. In the higher degrees of rarefaction, the water, however, became frozen.

Experiment 3.

The water, which had been previously exposed to the vacuum of the pump to free it from any air in solution, was weighed in a very sensible balance, before it was exposed to the action of the sulphuric acid under the receiver. Its temperature was 45°, and the height of the barometer 30·4. In half an hour's time it was again weighed, and the loss by evaporation was found to be 1·24 grains. It was replaced, and the air was rarefied till the gauge of the pump stood at 15·2; in the same interval of time it was re-weighed, and the loss was 2·72, but its temperature was reduced to 43°. The loss from evaporation, in equal intervals, with a pressure constantly diminishing one-half, was found to be as follows:—

Pressure.	Temperature. Beginning.	Temperature. End.	Loss. Grains.
30·4	45	45	1·24
15·2	45	43	2·87
7·6	45	43	5·49
3·8	45	43	8·80
1·9	45	41	14·80
·95	44	37	24·16
·47	45	31	39·40

When the exhaustion was pushed to the utmost, the gauge stood at 0·07, and the evaporation in the half-hour was 87·22 grains. During this last experi-

ment, the water was frozen in about eight minutes, while the thermometer under the ice denoted a temperature of 37°.

Now, before we infer from these experiments the state of evaporation from different degrees of atmospheric pressure, it is necessary to apply to the results a correction for the variation of temperature which took place during their progress. The quantity of evaporation having been determined to be in exact proportion to the elasticity of the vapour, we must estimate the latter from the mean of the temperatures before and after the experiments, and calculate the amount for any fixed temperature accordingly. This will, doubtless, give us a near approximation, although, from the last experiment, we perceive that the method of estimating the temperature of the surface water cannot be absolutely correct. The following Table presents us with the former results so corrected for the temperature of 45°.

Pressure.	Grains.
30·4	1·24
15·2	2·97
7·6	5·68
3·8	9·12
1·9	15·92
·95	29·33
·47	50·74
·07	112·32

Notwithstanding the slight irregularity of the above series, we can, I think, run no risk in drawing from it the conclusion, that the amount of evaporation

is, *cæteris paribus*, in exact inverse proportion to the elasticity of the incumbent air.

Before we proceed, it is necessary to say a few words upon the apparent discrepancy between the results of Dr. Dalton's experiments and mine, as to the amount of evaporation, at the full pressure of the atmosphere. He found, upon the supposition of no previous vapour existing in the air, that the full evaporating force of water, of the temperature of 45°, would be 1·26 grains per minute, from a vessel of six inches in diameter. This amount, reduced in proportion to the squares of the diameters of the two vessels, would give 7·65 grains in half an hour, from the glass of 2·7 inches diameter which I employed. It must, however, be recollected that Dr. Dalton's calculations were founded upon experiments made at a temperature very considerably above that of the surrounding medium, and that consequently a current must have been established in the latter which greatly accelerated the progress. It is true, that he afterwards subjected his calculations to the test of experience, at common atmospheric temperatures; but then he expressly states, that "when any experiment, designed as a test of the theory, was made, a quantity of water was put into one of the vessels, and the whole was weighed to a grain; then *it was placed in an open window, or other exposed situation*, for ten or fifteen minutes, and again weighed, to ascertain the loss by evaporation." In this way he ascertained that, with the same evaporating force, a strong wind would double the effect. The difference, however, even after

these considerations, is still very striking; but, from several repetitions of the experiment, I have no doubt of its exactness.

Experiment 4.

The arrangement described in the last experiment, having been found adequate to maintain in the receiver a state approaching to that of complete dryness, I had no opportunity of judging whether the elasticity of the vapour, as it rose from the surface of the water, varied in any degree with the pressure of the air, or whether any part of the increase of evaporation were dependent upon such variation. To determine this point, I placed the sulphuric acid in a glass, of the diameter of 2·8 inches, so that its surface was very little more than equal to that of the water. The vessels were placed side by side, upon the plate of the air-pump, and covered with the receiver. The temperature of the water and air was 52°, and the height of the barometer 29·8. The following Table shows the dew-point, which was obtained, at intervals of half an hour, at different degrees of atmospheric pressure:—

Barom.	Temp. of Water and Air.	Dew-Point.
29·8	52	36
14·9	53	37
7·45	52	35
3·72	53	36
1·86	52	34
·93	52	36
·15	52	36

The differences of these results are so extremely small, and are moreover so little connected with the

variations of density, that there can be no difficulty in regarding them as errors of observation, and we may conclude, that the elasticity of vapour, given off by water of the same temperature, is not influenced by differences of atmospheric pressure. The equal surfaces of sulphuric acid and water here made use of, maintained, at the temperature of 52°, a degree of saturation equal to 570. I repeated the experiment, at the temperature of 61°, and the following are the results:—

Barom.	Temp. of Water and Air.	Dew-Point.
29·6	61	48
14·8	61	49
7·4	60	48
3·7	61	50
1·85	61	48
·92	60	48
·15	61	48

Under these circumstances, the amount of saturation was 651; an increase evidently dependent upon the force of the vapour, but not in exact proportion to its augmentation.

Experiment 5.

Being now desirous of ascertaining in what degree the temperature of an evaporating surface would be influenced by differences in the density of the air, I made the following disposition of the apparatus:—To a brass wire, sliding through a collar of leathers, in a ground brass plate, I attached a very delicate mercurial thermometer: this was fixed, air-tight, upon the top of a large glass receiver, which covered a surface

of sulphuric acid of nearly equal dimensions with its base. Upon a tripod of glass, standing in the acid, was placed a vessel containing a little water, into which the thermometer could be dipped and withdrawn by means of the sliding wire. The bulb of the thermometer was covered with filtering paper. At the commencement of the experiment, the barometer was at 30·2 inches, and the temperature of the air 50°. Upon withdrawing the thermometer from the water, it began to fall very rapidly, and in a few minutes reached its maximum of depression. The following Table presents the results of the experiment, for different degrees of the air's density; the intervals were each of twenty minutes:—

Barom.		Temp. of Air.		Temp. of wet Ther.		Difference.
30·2	....	50	....	41	....	9
15·1	....	49	....	37	....	12
7·5	....	49	....	34	....	15
3·7	....	49·5	....	31·5	....	18
1·8	....	49·5	....	28·5	....	21
·9	....	49	....	24·5	....	24·5
·4	....	49	....	23	....	26

Here, in an atmosphere which a former experiment has proved to be in a state of almost perfect dryness, we find that, at the full atmospheric pressure, the wet surface of the thermometer was reduced 9°. It is worthy of remark, also, how small a quantity of water is required to produce this effect. It has been previously shown, that a surface of 2·7 inches diameter, only lost 1·24 grains in half an hour. This would have been 1·41 grains at the temperature of 49°. The surface of the wet thermometer could not have ex-

ceeded $\frac{1}{50}$th of that of the evaporating vessel, and the maximum effect was produced in ten minutes, or $\frac{1}{3}$rd of the time, so that the weight of water evaporated in this case was not more than (·0094 grains) one hundredth of a grain. It will be seen that the depression increased with the rarefaction of the air, but in the proportion only of the terms of an arithmetical progression to those of a geometrical. The increase is attributable, not to the augmented quantity of the evaporation, but to the decreased heating power of the atmosphere. MM. Dulong and Petit, in their experiments upon the cooling power of air, determined it to be nearly as the square root of the elasticity; but whether the heat which it is capable of communicating to a cold body, follow the same progression, the experiments above detailed are not sufficient to determine with precision. We may, however, certainly conclude from them, that the temperature of an evaporating surface is not affected by the mere quantity of evaporation.

It is right to remark that, in the last experiment, care was always taken to station the evaporating thermometer in the same place in the receiver, for I found that, when the air was highly rarefied, a greater degree of cold could be produced by approximating the wet bulb to the surface of the acid. No difference, however, could be perceived from such a change at the full atmospheric pressure. I also ascertained that no change of relative position in the surfaces of the acid and water produced any alteration in the dew-point under any circumstances.

§ 6. ORGANIC HYGROMETERS.

I now feel called upon to make a few observations upon other methods and instruments which have been contrived for estimating the amount of vapour at any time mixed with a gaseous atmosphere; but I should have thought it unnecessary, in the present advanced state of science and experience, to have instituted any comparison between the Dew-point Hygrometer and those instruments which have been constructed upon the hygroscopic properties of a hair, a gut, or the beard of an oat, had it not been for the curious fact that the meteorological registers of two of the first Observatories of Europe still record the observations of De Saussure's hair hygrometer, to the exclusion of any other*. In a recent edition (1840) of a *Treatise on Physics*, by M. G. Lamé, I find, moreover, the following strange assertion, with regard to all other hygrometers whatever: "Ces hygromètres ne sont pas employés a cause des manipulations exigées pour chaque observation qui les rendent moins commodes que celui de Saussure†." It is, therefore, with surprise that I feel obliged by such authority to repeat the answer which I made twenty years ago to the Editors of the *Bibliothèque Universelle*, of Geneva, who, in their number for March, 1820, gave an ac-

* I find, upon looking back in the *Annales de Chimie*, that the record of observations in that work has been discontinued since August, 1835, although the column for their insertion has been diligently maintained.

† Tom. i. p. 512.

count of my then recent invention, and their reason for preferring the hygrometer of their illustrious countryman De Saussure. In replying to their observations, I shall, it is to be presumed, answer the strongest statement that can be made in favour of hygroscopic substances.

In the first place, however, it is satisfactory to be able to record so strong a testimony to the accuracy of the combination as the following:—"On peut ne pas adopter toutes les théories de l'auteur ni partager sa prédilection pour l'appareil qui fait l'objet principal de son mémoire; mais *on ne peut disconvenir que cet appareil, tel qu'il est construit par M. Newman, fonctionne admirablement.*"

"Il est à présumer," say the learned Editors, "que l'auteur ne faisant mention nulle part dans son mémoire de l'hygromètre à cheveu, du feu De Saussure, n'en avait aucune connoissance; fait assez étrange vû la réputation qu'a acquise et que mérite à fort juste titre cet instrument pour toutes les recherches delicates. Il est pour le moins aussi sensible que celui de l'auteur; et pour la commodité du transport et de l'usage soit à l'air libre, soit en vases clos, l'hygromètre à cheveu l'emporte beaucoup. Il faut toujours faire une éxperience avec celui de l'auteur lorsqu'on veut connoitre l'état hygromètrique de l'air; il faut une provision d'éther, etc. Avec celui de De Saussure au contraire, il suffit de le regarder; en observant aussi le thermomètre dont les indications doivent toujours marcher pareillement à celles de l'hygromètre, ainsi que l'a prescrit soigneusement l'auteur dans son *Essai*

sur l'Hygrométrie, l'un des fruits les plus remarquables de sa sagacité et de son génie."

It would, indeed, have been strange, had the presumption been correct, that I was totally unacquainted with the instrument invented by that indefatigable philosopher. Long had I been an humble admirer of his sagacity and genius, and to no work have I been more indebted for useful instruction on the subject of which it treats, than to the Essay above referred to. My reason for not making mention of the hair-hygrometer of De Saussure, was, as I have before stated, the conviction on my mind of the general admission of the inadequacy of any application of organic substances to the required accuracy of the purpose. I had selected, on a previous occasion, the whalebone hygrometer of De Luc, as the best contrivance of this nature, to elucidate this point by contemporaneous observations with my own instrument; and the editors of the *Bibliothèque Universelle*, themselves, in recording my opinion "on verra combien ses indications sont vague et peu concluantes," add, "nous ne sommes pas très eloignés de cette opinion." Now, I must own, that I am quite at a loss to conceive any objection that can apply to the whalebone, that does not equally affect the hair as an accurate measure of vapour. But I shall prefer supporting this conclusion by the authority of others, rather than by any arguments of my own; especially, as I think, that I can produce authority, which the candour of the editors themselves will allow to be conclusive.

And let us hear the *Bibliothèque Universelle* itself

upon this very subject. First, as to the proper construction of the instrument. "Il en est peu qui exigent autant que l'hygromètre de l'adresse et des connoissances dans l'artiste qui l'entreprend; il devroit être physicien, mécanicien de tête et de main, et même un peu chimiste. La facilité de se procurer la substance hygrométrique qui fait l'âme de l'instrument a tourné à piège: on a cru que partout où l'on pouvoit se procurer des cheveux on fabriqueroit aisément les hygromètres; à la bonne heure s'il s'agit d'hygromètres quelconques; mais on n'en obtient de réguliers, comparables, durables que de la main d'un artiste expérimenté." Next, as to its permanency and the consequent reliance that may be placed upon its indications.

"Dans ceux qui ont longtemps éprouvés les inclémences de l'air, le cheveu acquiert un plus grande susceptibilité d'extension, et pour conservir à l'instrument une marche bien uniforme il seroit à-propos de changer le cheveu tous les deux ans*."

The Baron de Humboldt, the celebrated philosopher and traveller, who has had opportunities of making observations upon this subject which no other person ever yet enjoyed, and no other ever was more competent to appreciate, thus speaks of hygrometers in general, and of De Saussure's and De Luc's in particular†.

* *Bib. Univ.*, Avril, 1819.

† De Humboldt's *Travels*, translated by Helen Maria Williams. Vol. ii. p. 84, *et seq.*

"We know, by very accurate experiments, the capacities of saturation of the air at different degrees of the thermometer; but the relations which exist between the progressive lengthening of a hygroscopical body, and the quantities of vapour contained in a given space, have not been appreciated with the same degree of certainty. These considerations have induced me to publish the indications of the hair and whalebone hygrometers just as they were observed, marking the degree shown by the thermometers connected with these two instruments.

"As the fiftieth degree of the whalebone hygrometer corresponds to the eighty-sixth degree of the hair hygrometer, I made use of the first at sea and in the plains, while the second was generally reserved for the dry air of the Cordilleras. The hair, *below the sixty-fifth degree* of Saussure's instrument, indicates, by great variations, *the smallest changes of dryness*, and has, besides, the advantage of putting itself more rapidly into a state of equilibrium with the ambient air. De Luc's hygrometer acts on the contrary with extreme slowness; and on the summit of mountains, as I have often experienced to my great regret, we are often uncertain whether we have not ceased our observations before the instrument has ceased its movement. On the other hand, this hygrometer, furnished with a spring, has the advantages of being strong, *marking with great exactness, in very moist air*, the least increment of the quantity of vapour in solution, and acting in all positions; while Saussure's hygrometer must be suspended, and is often deranged

by the wind, which raises the counterpoise of the index. I have thought that it might prove useful to travellers to mention in this place the results of an experience of several years." "*Notwithstanding the doubts which have been raised in these latter times respecting the accuracy with which hair or whalebone hygrometers indicate the quantity of vapours mingled in the atmospheric air;* it must be admitted, that even in the present state of our knowledge, these instruments are highly interesting to a naturalist, who can transport them from the temperate to the torrid zone, from the northern to the southern hemisphere, from the low regions of the air which rest on the sea, to the snowy tops of the Cordilleras."

"I have never been able to reduce the hair or whalebone to the degree of extreme siccity for want of a portable apparatus, which I regret not having made before my departure. I advise travellers to provide themselves with a narrow jar containing caustic potash, quick-lime, or muriate of lime, and closed with a screw, by a plate on which the hygrometer may be fixed. This small apparatus would be of easy conveyance, *if care were taken to keep it always in a perpendicular position.* As under the tropics, Saussure's hygrometer generally keeps above 83°, a frequent verification of the single point of humidity is most commonly sufficient to give confidence to the observer. Besides, in order to know on which side the error lies, we should remember that old hygrometers, if not corrected, have a tendency to indicate too great dryness."

Sir John Leslie, in his *Essay upon the relations of Air to Heat and Moisture*, makes the following remarks upon the same subject. "But these substances (*viz.*, hygroscopic substances), especially the harder kinds of them, unless they be extremely thin, receive their impressions very slowly, and hence they cannot mark with any precision the fleeting and momentary state of the ambient medium." "The expansion of the thin cross-sections of box, or other hard wood, the elongation of the human hair, or a slice of whalebone, and the untwisting of the wild-oat, of cat-gut, of a cord or linen thread, and of a species of grass brought from India, have, at different times, being used with various success. But the instruments so formed are either extremely dull in their motions, or, if they acquire greater sensibility from the attenuation of their substance, they are, likewise, rendered the more subject to accidental injury and derangement, and all of them appear to lose, in time, insensibly, their tone and proper action."

But it is to the Essay of M. de Saussure himself, that I might appeal with the most confidence, for the confirmation of this opinion. It is replete with acknowledgments of the obvious defects of instruments constructed upon this principle; defects which it was impossible that a mind like his could overlook or attempt to conceal: and it proves fully that his sagacity and genius were tasked to the utmost, to diminish the sources of uncertainty which it was out of his power wholly to remove. Any person, who had not seen the minute instructions given by this able philo-

sopher for the construction of his hygrometer, would be surprised at the nicety required in its adjustment. The mere preparation of the hair is a process of great delicacy and uncertainty. It is as a preliminary step exposed to an alkaline lixivium, upon the due strength and regulated application of which its most valuable properties depend; and hairs which have been unequally exposed to this action are no longer fit for comparison with one another. "Les cheveux n'ont une marche parallèle que quand ils sont également lessivés." So that it would be impossible for an artist in London, although he were "*physicien, mécanicien de tête et de main, et même un peu chimiste,*" with the most scrupulous attention to the directions contained in this Essay, to construct an instrument which should range with one made in Geneva, unless he had the means of actual comparison.

But after all the care which the ingenuity of such a philosopher could devise (and none but such a philosopher could be competent to take the necessary precautions), he, the inventor speaks thus guardedly and candidly of the best instruments. "Quant à la comparabilité des hygromètres construits avec cette substance je puis dire que deux ou plusieurs de ces instruments, faits avec des cheveux semblablement préparés, gradués sur les mêmes principes, et exposés ensuite aux mêmes variations d'humidité et du sécheresse, ont des marches *que l'on peut nommer* parallèles. Je ne dirai cependant pas qu'ils indiquent toujours tous le même degré, mais que leurs écarts vont rarement au delà de deux degrés. Si après que deux hygromètres auront séjournés, pen-

dant long-temps dans un air très sec, par exemple, au quarantième degré de ma division, on en porte un dans un air encore plus sec, qui le fasse venir, je suppose, à trente, et que pendant ce temps-là, l'autre ait été porté dans un air un peu moins sec, par exemple à cinquante degrés; qu'ensuite on les replace tous les deux dans l'air où ils étoient d'abord, *ils ne reviendront ni l'un ni l'autre à quarante;* celui qui vient de l'air le moins sec restera à quarante-deux ou quarante-trois; et celui qui vient de l'air le plus sec ne montera qu'à trente-sept ou trente-huit." "Cet hygromètre a l'inconvénient de ne pas revenir bien exactement au même point lorsqu'on l'agite un peu fortement, ou qu'on le transporte d'un lieu dans un autre, parceque le poids de trois grains qui tient la lame d'argent tendue, ne peut pas la ployer assez exactement pour la forcer à se coller toujours avec la même précision contre l'arbre autour du quel elle se roule: or on ne peut pas augmenter sensiblement le poids sans des inconvéniens plus grands encore. D'ailleurs si le cheveu est trop long, le vent, lorsqu'on observe en plein air, a trop de prise sur lui, et communique ainsi à l'aiguille des oscillations incommodes."

The relation of the degrees of this hygrometer, to the actual quantity of vapour in the air, is moreover very far from having been determined; "C'est ce que j'ai tenté de faire," says the inventor, "pour mon hygromètre; mais on verra que ce travail difficile est encore bien loin de sa perfection."

When we add to these admissions of the inventor the disturbing influence of heat, which is so great, that

the mere approach of the hand causes a sensible movement towards dryness*; the adhesion of dust and spiders' webs; the choking of the pivot of the wheel; and the possibility of friction from the index; we shall have some notion of the sources of error in this instrument, which the great philosopher, its inventor, himself has pointed out and laboured to modify.

It is thus that I reply, or rather it is thus that universal experience replies, to the "pour le moins aussi sensible," of the editors of the *Bibliothèque Universelle*. As to the "commodité du transport et de l'usage," I must remark, that the whole of the new apparatus packs in a box, which may very conveniently be carried in the pocket; and although each observation with it may, in strictness, be called an experiment, yet that infinitely less time is required to make this experiment, than would be necessary to assure an observer, with either the hair or whalebone hygrometer, that "the instrument had ceased its movement." The inconvenience of carrying a supply of ether, may, I think, fairly be set against that of an apparatus for rectifying the instruments described by De Humboldt, and which he considers necessary to give confidence in their indications.

But upon this point I shall avail myself of direct evidence of the most unexceptionable nature.

Mr. Caldcleugh, in his "Observations in Brazil, and on the Equator†," remarks, "When I commenced using the instrument, I was almost afraid to touch it, from its

* M. Gay Lussac. † *Quart. Journ. of Science*, vol. xiv. p. 46.

apparent delicacy, but was soon convinced, from the many rude shocks it underwent, that it was stronger than I had imagined; more than common carelessness, indeed, is required to break it. I may be permitted to add, that I think no traveller will find any inconvenience from carrying this hygrometer or its accompaniment, a small stock of ether; the latter I usually placed among my linen."

Colonel Sabine, also, after twelve months' experience between the tropics, during which time he daily made numerous observations, thus bears testimony to the same fact:

" I have great pleasure in remarking, that I found much less difficulty than I had anticipated in getting corresponding observations made with the hygrometer, on the correctness of which I could depend; the ingenuity in the principle of this instrument, and the simplicity of its application, together with the decisive nature of the results which it gives, independent of the labour, and, at least, the uncertainty of *formulaic* deduction, form its great advantage over the methods by evaporation, or the indications of hygroscopic substances: these particulars excite an interest in its trial, in persons to whom it was previously unknown, which is probably the reason that the distrust, which is almost always in the first instance expressed, of precision in the observation itself, is found to give way in practice so much sooner than might be supposed. It may be useful, also, to travellers in warm climates, to add a remark from my own experience, that in ascending elevations, or in journeying inland over rough roads,

the ether carries perfectly well in a bottle in the waistcoat-pocket, with a common cork capped with leather; and that the expenditure of ether altogether, will probably fall much short of the estimate, as with ordinary care, very little will be wasted*."

The quantity of ether expended by Colonel Sabine during the year, fell something short of a pint.

The dew-point hygrometer may be still further judged by the very competent authority to which I have been referred. M. de Saussure sums up, in his Essay, the qualities which a perfect hygrometer ought to possess; allowing, candidly, that his own falls very short of the perfection which he proposes. All I would ask is, if the one which I have invented fulfil all the conditions laid down as follows, that for the good of science it may be adopted as a standard by experimental philosophers.

"Un hygromètre seroit parfait: premièrement si les variations étoient assez étendues pour rendre sensibles les plus petites différences d'humidité, et de sécheresse.

2. "Si elles étoient assez promptes pour suivre pas-à-pas toutes celles de l'air, et pour indiquer toujours exactement son état actuel.

3. "Si l'instrument étoit toujours d'accord avec lui-même, c'est-à-dire, qu'au retour du même état de l'air il se retrouvât toujours au même degré.

4. "S'il étoit comparable, c'est-à-dire, si plusieurs hygromètres construits séparément sur les mêmes prin-

* *Quart. Journ. of Science*, vol. xv. p. 71.

cipes indiquoient toujours le même degré dans les mêmes circonstances.

5. "S'il n'étoit affecté que par l'humidité ou la sécheresse proprement dites.

6. "Enfin si ces mêmes variations étoient proportionnelles à celles de l'air, en sorte que dans des circonstances pareilles, un nombre double ou triple de degrés indiquât constamment un quantité double ou triple de vapeurs."

§ 7. WET-BULB HYGROMETER.

But there is yet another method of estimating the quantity of moisture at any time existing in the air, which is not liable to the same class of objections as those which we have been just considering; I mean that of a comparison between the temperatures of a moist and a dry thermometer. Dr. Hutton was the first who conceived the idea of applying such an observation to the purposes of hygrometry. "I used to amuse myself," says he, "in walking in the fields by observing the temperature of the air with the thermometer, and trying its dryness by the evaporation of water. The method I pursued was this: I had a thermometer included within a glass tube, hermetically sealed: this I held in a proper situation until it acquired the temperature of the atmosphere, and then I dipped it into a little water, also cooled to the same temperature. I then exposed my thermometer, with its glass case thus wetted, to the evaporation of the atmosphere, by holding the ball of the

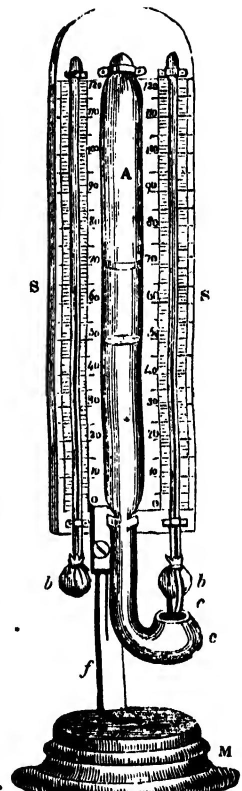
thermometer, or end of the tube in which the ball was included, towards the current of the air; I examined how much the evaporation from that glass tube cooled the ball of the thermometer which was included."

Now this simple observation, it is probable, may furnish the necessary *data* for solving the problem in all its particulars; but if it do, it is by means of abstruse calculations, and many delicate corrections, upon which philosophers are by no means agreed.

Sir John Leslie founded upon it an instrument, upon which he expended much ingenuity and research: it consists of an air-thermometer, one of the balls of which is covered with muslin, and kept moist; but in departing from the simplicity of the original experiment, he has multiplied the sources of error, both in construction and observation. He has, moreover, substituted an arbitrary scale for that of the common thermometer; and his hygrometer possesses a deceptive sensibility, which is liable to be affected by more causes than those which can be taken into account.

The observation is made in its most unexceptionable manner by means of two perfectly similar and equal thermometers compared together throughout their scales. The bulb of one is superficially covered with some bibulous substance, and kept continually moist by the percolation of a little water. Various contrivances have been made for facilitating the observation, the most convenient of which, perhaps, is that of Dr. Mason.

Upon the stand M is fixed an upright rod of brass, *f*, supporting the scale SS, in the middle of which a



space is left to receive a glass tube, A, formed on the principle of the bird-fountain, having on each side of it a thermometer, *bb*. The bulbs of these thermometers are covered with white silk, but round the stem of one, a thread of floss-silk, *e*, is attached, which terminates in the cup of the fountain, *c*. This bulb being thus in connexion with a reservoir of water, is kept wet by capillary attraction; and as evaporation is constantly taking place, its temperature is reduced below that of the other bulb.

Dr. Apjohn has most ably and patiently investigated the circumstances which it is necessary to take into consideration in rendering this observation available to the determination of the dew-point of an atmosphere in which it may be made, and from their recapitulation it will be seen how numerous and delicate and complicated they are.

When in the moist-bulb hygrometer the stationary temperature is attained, the heat which vaporizes the water is assumed to be necessarily equal to that which the air imparts in descending from the temperature of the atmosphere to that of the moistened bulb. It is also assumed that the air which has undergone this reduction becomes saturated with moisture. In calculat-

ing from these assumptions, the weight of water which would be converted into vapour by the heat which a given weight of air would evolve in cooling from the temperature of the atmosphere to that of the moistened bulb, it is not only necessary to know the tension of vapour for every degree of the thermometer within the atmospheric range, but the specific heat of air must be taken into account as well as the latent heat of steam, (caloric of elasticity.)

The latent heat of steam, however, varies, as is well known, with the temperature; but in the formula for the calculation which we shall presently give, the latent heat of steam at 50°, (1129°,) is taken as a sufficiently near approximation.

The specific heat of air varies also with the pressure, and upon the exact law of this variation different opinions are entertained. In the formula it is assumed that the differences of the specific heats under a constant volume are proportional to the differences of pressure.

If we allow that these several approximate results are sufficiently near for ordinary purposes, an important objection remains to the observation of the moist-bulb hygrometer. It might be true, if no other agencies were taken into account, that when it has attained its stationary temperature, the quantities of heat which it loses and gains in a given time are perfectly equal, and that the heat lost is entirely employed in converting the water into vapour; but the whole of the acquired heat is not necessarily derived, though this is assumed to be the case, from the air cooled by contact with the

bulb of the instrument. In fact, the hygrometer is in the predicament of a cool body placed in a warm medium, and it must consequently receive from surrounding bodies by radiation a greater amount of heat than it imparts to them in virtue of the same process, and this will even vary, as we know, with the state and colour of its surface. Dr. Apjohn acknowledges that this disregarded influence must be of sufficient magnitude to exert an appreciable influence, and regrets his inability to assign any means of determining its amount.

Amongst the objections to the instrument, we must not omit the smallness of the scale which the thermometer as commonly constructed affords. For accurate results it is necessary to observe the tenths of Fahrenheit's degrees, and the probable errors of observation bear a very high proportion to the required result, particularly about the freezing point. An error in reading of half a degree would affect the observation with an error of $\frac{1}{35}$th of the whole amount at the temperature of 32°; while the same error at 80° would only occasion an inaccuracy of about $\frac{1}{300}$th.

But a much more important objection must be made to the wet-bulb hygrometer than any that has been yet pointed out, if we may rely upon the experiments of M. Peltier*.

This gentleman has shown that from a surface charged with resinous electricity the process of evapo-

* On the Cause of the Electric Phenomena of the Atmosphere, by M. A. Peltier.—*Ann. de Chim.*, Avr. 1842.—Taylor's *Memoirs*, vol. iii. p. 377.

ration in the atmosphere is more rapid than from the same surface in a neutral state, and he has even made "an electric hygrometer, founded on the proportionality which exists between the loss of electricity and the quantity of vapours contained in the atmosphere."

Now, if the process of evaporation be at all under the influence of the variable tension of atmospheric electricity, it is clear that any formula for estimating the dew-point, founded upon the hypothesis that such process is wholly dependent upon calorific influence, must lead to erroneous results: and it is not at all improbable that in some such unappreciated influence the explanation will be found of those negative results in which the temperature of the wet thermometer has been found above that of the dry, which occur in all long series of such observations, and which have been ascertained with the greatest care in the Greenwich observations.

The formula for the calculation of the elasticity of steam, from the observation of the moist-bulb hygrometer, as finally corrected by Dr. Apjohn, is as follows:—

$$f'' = f' - \frac{d}{88} \times \frac{p}{30}$$

wherein f'' denotes the tension of steam at the dew-point: f' = the tension of steam at the observed temperature of the air: d = the depression of the moist surface: 88 (or possibly 87) = a coefficient dependent upon the specific heat of the air, and the latent heat of the vapour: p = the existing pressure of the air: 30 = the mean pressure of the air.

Dr. Apjohn has, moreover, calculated the subjoined

table* by which the determination of the dew point from the formula is greatly facilitated. It gives $\frac{d}{87 \times 30}$ for every value of d between 0·1 and 10. In calculating an observation, this quotient, as is obvious from the formula, is to be multiplied by p, the existing pressure, and the product, when deducted from f', as given by a table of the elastic force of vapour at different temperatures, will afford f'', or the tension of vapour at the dew-point. Should the depression exceed 10°, the value of $\frac{d}{87 \times 30}$ may still be derived from the table by addition. Thus, if $d = 13°$ $\frac{d}{87 \times 30} = \cdot00383 + \cdot00114 = \cdot00497$.

TABLE (XII.) *for Calculating the Elasticity of Atmospheric Vapour by the Wet-Bulb Hygrometer.*

d	$\frac{d}{87 \times 30}$	d	$\frac{d}{87 \times 30}$	d	$\frac{d}{87 \times 30}$	d	$\frac{d}{87 \times 30}$	d	$\frac{d}{87 \times 30}$
·1	·00003	2·1	·00080	4·1	·00157	6·1	·00233	8·1	·00310
·2	·00007	2·2	·00084	4·2	·00160	6·2	·00237	8·2	·00313
·3	·00011	2·3	·00087	4·3	·00164	6·3	·00241	8·3	·00317
·4	·00015	2·4	·00091	4·4	·00168	6·4	·00245	8·4	·00321
·5	·00019	2·5	·00095	4·5	·00172	6·5	·00248	8·5	·00325
·6	·00022	2·6	·00099	4·6	·00176	6·6	·00252	8·6	·00329
·7	·00026	2·7	·00103	4·7	·00180	6·7	·00256	8·7	·00333
·8	·00030	2·8	·00107	4·8	·00183	6·8	·00260	8·8	·00337
·9	·00034	2·9	·00111	4·9	·00187	6·9	·00264	8·9	·00340
1·	·00038	3·	·00114	5·	·00191	7·	·00268	9·	·00344
1·1	·00042	3·1	·00118	5·1	·00195	7·1	·00271	9·1	·00348
1·2	·00045	3·2	·00122	5·2	·00199	7·2	·00275	9 2	·00352
1·3	·00049	3·3	·00126	5·3	·00202	7·3	·00279	9·3	·00356
1·4	·00053	3·4	·00130	5·4	·00206	7·4	·00283	9·4	·00360
1·5	·00057	3·5	·00134	5·5	·00210	7·5	·00287	9·5	·00363
1·6	·00061	3·6	·00137	5·6	·00214	7·6	·00291	9·6	·00367
1·7	·00065	3·7	·00141	5·7	·00218	7·7	·00294	9·7	·00371
1·8	·00068	3·8	·00145	5.8	·00222	7·8	·00298	9·8	·00375
1·9	·00072	3·9	·00149	5·9	·00225	7·9	·00302	9·9	·00379
2·	·00076	4·	·00153	6·	·00229	8·	·00306	10·	·00383

* *Phil. Mag.*, 1835, vol. vii., p. 473.

When the reading, however, of the wet thermometer is lower than 32°, the formula becomes $f'' = f' = \frac{d}{96} \times \frac{p}{30}$ because the latent heat of water, as well as the latent heat of steam, must be taken into account, inasmuch as the heat evolved has first to liquefy ice, and then to convert the water into vapour.

Notwithstanding the assistance afforded by this table, it will be observed that the formula calculations for obtaining the dew-point from the inspection of the moist-bulb hygrometer, without regarding the uncertainty of some of the data upon which they are founded, are tedious and troublesome, and would certainly occupy more time than would be necessary for carefully ascertaining the same point by the direct method. But little is gained, or, more frequently, every thing is lost, by this transfer of labour from the observer to the computator. Notwithstanding the thousands of observations which have been made, probably no one ever sat down to calculate and discuss the results of a twelvemonth's observations of either the hair or moist-bulb hygrometers. And without such reduction, what useful ideas, beyond the vague one of greater or less degrees of dryness, are their registers capable of conveying to the mind? On the contrary, the comparatively limited use which has hitherto been made of the dew-point hygrometer has led to the most valuable and precise conclusions concerning one of the most important and ever-varying ingredients of the atmospheric mixture, in the different climates in which the observations have been made. The moist-bulb hygrometer is doubtless much to be preferred to any hygroscope dependent

upon the absorbing powers of an organic substance, but it would be but an idle excuse for any one who had an opportunity of observing both to prefer the former on account of the mere facility of the first observation. Either a hygroscope or a wet-bulb hygrometer might legitimately be used, in a long series of observations, to warn the observer of any change in the hygrometric relations of the atmosphere, which he would then proceed to verify and measure by the dew-point hygrometer.

The safest deductions from the differences between the dry and wet thermometers are those which may be derived from a long series of experimental comparisons with the differences between the dew-point and the temperature of the air, which, as bearing a fixed ratio to each other, may probably be depended upon, at least in the locality in which the observations were made. The Astronomer Royal has thus constructed from the Greenwich Observations a table of the values of the fraction

$$\frac{\text{Difference between Dew-Point and Temperature of the Air}}{\text{Difference between Evaporation Temperature and Air Temperature}}$$

The difference between the dry and wet thermometer multiplied by these factors according to the temperature, and deducted from the temperature of the air, will give a close approximation to the dew-point.

Suppose the observation to have been—

$$\overset{\text{Air.}}{51{\cdot}5^\circ} - \overset{\text{Evap.}}{46{\cdot}7} = \overset{\text{Diff.}}{4{\cdot}8}.$$

$$\overset{\text{Diff.}}{4{\cdot}8} \times \overset{\text{Factor.}}{2} = 9{\cdot}6.$$

$$\text{And } 51{\cdot}5 - 9{\cdot}6 = \overset{\text{Dew-point.}}{41{\cdot}9}.$$

The observations were divided into groups, according to every five degrees of air temperature; and the following are the results:—

Table XIII. *Greenwich Factors for finding Dew-Point from Temperature of Evaporation.*

Temp. of Air between	20 & 25,	the fraction	= 9°·0....	1 observ.
„	25 & 30	„	= 5·2....	31 „
„	30 & 32	„	= 4·1....	47 „
„	32 & 35	„	= 2·8....	99 „
„	35 & 40	„	= 2·5....	187 „
„	40 & 45	„	= 2·2....	332 „
„	50 & 55	„	= 2·0....	373 „
„	55 & 60	„	= 1·7....	339 „
„	60 & 65	„	= 1·7....	228 „
„	65 & 70	„	= 1·6....	137 „
„	70 & 75	„	= 1·5....	55 „
„	75 & 80	„	= 1·5....	24 „
„	80 & 85	„	= 1·6....	8 „
„	85 & 90	„	= 1·7....	2 „

From a comparison of two years' observations at Greenwich of the wet-bulb hygrometer with those of the dew-point hygrometer, it appears that the extreme differences, by Dr. Apjohn's formula, are—

− 3°·9 between 65 & 70;
and + 3°·6 between 75 & 80.

Whilst the extreme differences by the Greenwich factors are—

− 3°·7 between 75 & 80;
+ 5°·6 between 75 & 80.

Thus an appeal must still be made to the dew-point hygrometer, whilst we are seeking to become better acquainted with the almost infinitely varying circumstances by which the evaporation hygrometer is affected.

TABLE XIV. *Elastic Force of Aqueous Vapour for every Degree of Temperature from 0° to 124° Fahr.**

Temp. Fahr.	Force. Inches of Mercury.	Temp. Fahr.	Force. Inches of Mercury.	Temp. Fahr.	Force. Inches of Mercury.	Temp. Fahr.	Force. Inches of Mercury.
0°	0·051	32°	0·186	63°	0·570	94°	1·562
1	0·053	33	0·193	64	0·590	95	1·610
2	0·056	34	0·200	65	0·611	96	1·660
3	0·058	35	0·208	66	0·632	97	1·712
4	0·060	36	0·216	67	0·654	98	1·764
5	0·063	37	0·224	68	0·676	99	1·819
6	0·066	38	0·233	69	0·699	100	1·874
7	0·069	39	0·242	70	0·723	101	1·931
8	0·071	40	0·251	71	0·748	102	1·990
9	0·074	41	0·260	72	0·773	103	2·050
10	0·078	42	0·270	73	0·799	104	2·112
11	0·081	43	0·280	74	0·826	105	2·176
12	0·084	44	0·291	75	0·854	106	2·241
13	0·088	45	0·302	76	0·882	107	2·307
14	0·092	46	0·313	77	0·911	108	2·376
15	0·095	47	0·324	78	0·942	109	2·447
16	0·099	48	0·336	79	0·973	110	2·519
17	0·103	49	0·349	80	1·005	111	2·593
18	0·107	50	0·361	81	1·036	112	2·669
19	0·112	51	0·375	82	1·072	113	2·747
20	0·116	52	0·389	83	1·106	114	2·826
21	0·121	53	0·402	84	1·142	115	2·908
22	0·126	54	0·417	85	1·179	116	2·992
23	0·131	55	0·432	86	1·217	117	3·078
24	0·136	56	0·447	87	1·256	118	3·166
25	0·142	57	0·463	88	1·296	119	3·257
26	0·147	58	0·480	89	1·337	120	3·349
27	0·153	59	0·497	90	1·380	121	3·444
28	0·159	60	0·514	91	1·423	122	3·542
29	0·165	61	0·532	92	1·468	123	8·641
30	0·172	62	0·551	93	1·514	124	3·743
31	0·179						

* Calculated by Mr. Galbraith, upon Mr. Ivory's formula, from the experiments of Dr. Ure.

ON THE

RADIATION AND ABSORPTION

OF HEAT

IN THE ATMOSPHERE.

ON THE

RADIATION AND ABSORPTION OF HEAT IN THE ATMOSPHERE.

A PERIOD of twenty years has passed since the publication of the following Essay upon the Radiation of Heat in the Atmosphere. It was the first attempt that had ever been made to systematize observations upon a subject of very great meteorological interest; but the observations which it recorded were necessarily of a very imperfect kind, and avowedly insufficient for the quantitative determination of the physical laws of the phenomena. At the time, however, it excited considerable interest, which has gone on increasing, till, in far abler hands, and with the assistance of a new and beautiful instrument, which will be presently described, one branch of the subject has been found capable of a mathematical discussion which will probably ere long, by the more general use of the same instrument, be extended to other branches.

In the mean time the investigation has asumed a new aspect, since the beautiful and important discovery of M. Melloni, of calorific rays of different properties, analogous in some degree to the difference between luminiferous rays. These rays are differently absorbed and transmitted by different media, just as the differently-coloured rays are absorbed and transmitted by other media; the diathermancy of different bodies,

however, not at all agreeing with their transparency. One of the most important of the properties of radiant heat, and in which it differs from light, is the capability of one kind of rays being converted into another by absorption and secondary radiation; so that, for example, the direct rays of the sun, which, falling upon a surface of snow, would be almost entirely reflected without melting the snow, being first absorbed and then re-emitted from a piece of dry timber, would melt it wherever they impinged.

The whole subject of atmospheric radiation, it is obvious, requires reconsideration with regard to these important distinctions; and a new field of observation and experiment has thus become revealed to us, which will require fresh opportunities and probably new instruments of research.

Notwithstanding this extension of our views, I am of opinion that the following observations will still be found of importance, were it only in the practical point of view, for ascertaining, as a circumstance of considerable interest amongst the particulars of different climates, the maximum degree of heat to which a plant, or the parts of a plant, may be subjected by a full exposure to the sun, under the most favourable circumstances. Amongst them, also, will be found some approximate estimations of the force of the secondary radiation of terrestrial objects at different periods of the day, and some indications of specific differences in the rays of heat which permeate the atmosphere.

As measures of the force of radiation in different latitudes, it must be allowed that they possess little

value, on account of the disturbing influences of which it was impossible at the time to take any account; they have, however, excited an inquiry upon the subject which the use of the actinometer, it is to be hoped, will speedily satisfy.

The radiation of heat is a subject of the utmost interest and importance, and the difficulties which surround it have exercised the ingenuity and industry of some of the greatest philosophers of modern times. Count Rumford, Professor Leslie, Sir Humphry Davy, Professor Prevost, Dr. Delaroche, and MM. Dulong and Petit, have particularly distinguished themselves by their experiments and reasonings upon it; and the last-named gentlemen, more especially, have demonstrated some of the laws of the distribution of heat, with mathematical precision. To the above list we may now add the names of M. Melloni, Sir John Herschel, and Professor Forbes.

With regard to the influence of radiation in the economy of nature, however, but little is at present known; and the elegant and* demonstrative Essay of the late Dr. Wells upon the formation of dew, stands almost alone in exhibiting its important connexion with the welfare of the vegetable kingdom. His successful labours were directed to one particular branch of, what would appear to be, a very extended inquiry; for there can be little doubt that radiant caloric must have a direct and very important influence upon many of the processes of vegetation.

It is with a view of exciting some attention to a subject which appears to me to be so well worthy of

elucidation, and to suggest some experiments, which, to render them beneficial, require much perseverance and extensive co-operation, that I venture to bring forward some observations of my own, although I am sensible they are in a very imperfect state; but to which I have devoted much attention, particularly during the years 1819, 1820, and 1821. I hesitate the less to do so, as I am enabled, by the kindness of my friend Colonel Sabine, (whose zeal for science prompted him, amidst the laborious operations connected with more important objects, to devote much of his leisure time to the study of atmospheric phenomena,) to give them additional interest, by combining with them his experiments in tropical climates.

It often struck me with surprise, that, in the numerous meteorological registers which had been published in different parts of the world, no one had ever thought of including observations upon the intensity of the solar rays at different seasons of the year, and in different situations. It is well known to the agriculturist and the gardener, that without the direct influence of the sun, whatever may be the temperature of the air, the fruits of the earth seldom come to perfection. What, then, is the force of this important agent? what the modifications to which it is subject? and how is its energy spent, when screened by concrete vapours from the surface of the earth? Does its influence increase with the temperature of the air from the pole to the equator? or is the rapid vegetation of the arctic regions, during the short summer of those climates, dependent upon any compensating energy of its operation? Before I attempt to answer

these questions, I will propose another, which, many will be surprised to find, cannot be met with an immediate solution; which is, the maximum degree of heat to which a plant, or the parts of a plant, are subjected by exposure to a mid-day sun at midsummer in this climate?

Many persons have, at different times, exposed naked thermometers to the direct light of the sun, and marked their rise; but such trials have never been persevered in, or registered with any exactness. Nor were the means employed calculated to resolve the problem with any precision. Few of the rays would impinge directly upon the bulb of the instrument so placed, and all, but the direct rays, would be reflected from it. The results would necessarily vary with size and shape, and no two thermometers would, probably, agree in their indications.

There are, no doubt, in all the plants of the vegetable kingdom parts which are calculated to absorb all the radiant heat which strikes upon them; and therefore it is desirable to know, with a reference to this subject alone, the utmost amount of temperature which solar radiation is capable of producing.

In my own meteorological register I therefore included a column for observations upon this point. These are complete from November, 1820, to the end of December, 1821, and from the beginning of May, 1822, to the end of August of the same year. They were made by means of a register thermometer of large range, having its bulb covered with black wool, and placed upon a south border of garden mould, with

a full exposure to the sun. The thermometer did not rest upon the earth, but was supported about an inch above it. The arrangement was by no means unobjectionable, but the irregularities, to which it was liable, would, it was hoped, be, in a great measure, balanced by the multitude of the observations. The maximum heat of the sun's rays during the day was thus measured and entered in the journal. The following Table presents us with the mean greatest height of the black thermometer above the surrounding medium for every month in the year, together with the utmost intensity observed in the same periods. The first column exhibits the month, the second the mean maximum temperature of the air, the third the average effect, and the fourth the maximum energy of the sun's light.

TABLE XV. *Shewing the mean maximum Temperature of the Air, with the mean and maximum Power of the Sun, for every Month of the Year.*

	Mean Maximum of the Air.	Mean Maximum Force of Solar Radiation.	Maximum Force of Solar Radiation.
January . .	39·6	4·4	12
February . .	42·4	10·1	36
March . . .	50·1	16	49
April . . .	57·7	28·1	47
May	62·9	30·5	57
June . . .	69·4	39·9	65
July	69·2	25·8	55
August . . .	70·1	33·1	59
September . .	65·6	32·7	54
October . .	55·7	27·5	43
November . .	47·5	6·7	24
December . .	43·2	5·4	12

Hence it appears that, as it might have been predicted, the power of solar radiation follows the course of the sun's declination. The maximum intensity and effect occur in June, while the greatest mean temperature of the atmosphere does not take place till July. This arrangement, no doubt, has an important influence upon the processes of fructification in the vegetable kingdom. Agriculturists are well aware of the advantage of direct solar heat in the flowering of wheat, and other corn-crops; an advantage which is never compensated by any elevation of temperature under a clouded sky. A Table, similar to that above given, founded upon the experience of several years, would furnish a very valuable standard of comparison, and the causes of fruitful and unfruitful seasons would, no doubt, be found to be intimately connected with the particulars of which it would be composed. For example, it will be seen in the register, that in the very fruitful year of 1822, the force of the sun's radiation in May was 7°, and in June 5°, above the corresponding months of the year 1821, in which the crops of corn were universally blighted and mildewed. The discordances above exhibited would also be found to vanish in a more extended average, and a more regular progression would be elicited from the balance of disturbing causes.

I have also been at some pains to ascertain the progression of radiation from the sun from its rising to the meridian, and from the meridian to its setting. The following are the details of a series of observations, made for this purpose in the month of June,

1822. The day was perfectly calm and cloudless, and the atmosphere so clear that the disc of the moon was visible throughout the day. The dew-point, by the hygrometer, was stationary at 57°, and only a few light *cirri* were discernible in the south-east quarter of the heavens.

TABLE XVI. *Showing the Progress of Solar Radiation from Morning to Evening.*

Thermometer.			
Time.	In Sun.	In Shade.	Difference.
A.M. 9	93	68	25
9½	103	69	34
10	111	70½	40½
10½	119	71	48
11	124	71½	52½
11½	125	72½	52½
12	129	73	56
P.M. 0½	132	74	58
1	141	74½	66½
1½	140	75	65
2	143	75½	67½
2½	138	76	62
3	138	76½	61½
3½	132	77	55
4	124	76	48
4½	123	77	46
5	112	76	36
5½	106	75	31
6	100	73	27
Means	124¾	73½	51¼

The mean results of five series of experiments, conducted with every possible precaution, are contained in the following Table, showing the power of the sun's

radiation from $9\frac{1}{2}$ A.M. to $6\frac{1}{2}$ P.M., in the month of June.

TABLE XVII. *Showing the Progress of the Solar Radiation from Morning to Evening in June, upon an average of five Experiments.*

Time.	Force of Sun's Rays.
$9\frac{1}{2}$ A.M.	32
$10\frac{1}{2}$	46
$11\frac{1}{2}$	55
$12\frac{1}{2}$	63
$1\frac{1}{2}$ P.M.	65
$2\frac{1}{2}$	63
$3\frac{1}{2}$	58
$4\frac{1}{2}$	49
$5\frac{1}{2}$	35
$7\frac{1}{2}$	29

Some important questions now present themselves, which in the present state of our knowledge cannot, I fear, be answered satisfactorily. It may, however, be of some use to point them out as objects of future investigation*. As the mean effect of the sun's radiation upon the surface of the earth falls so much short of the impression which it is capable of producing, in what way is its energy spent? Is it absorbed or dissipated in mid air? How is the mean temperature affected by it? How does it modify the ascending gradation of temperature in the atmosphere? What is its influence upon the concrete vapour of the

* Since the preceding remarks were written, a paper by Professor J. D. Forbes, bearing upon some of these points, has been published in the *Phil. Trans.* for 1842, some of the results of which are mentioned in the subsequent additions to this Essay.

clouds? Is it not the source of partial and very unequal expansions and contractions in the aërial medium?

Before I proceed to detail some experiments which are connected (but slightly, I fear,) with these interesting inquiries, I shall avail myself of Colonel Sabine's kind assistance, in instituting a comparison of the radiant power of the sun in different latitudes.

The first series of experiments to which I shall refer, were made in March, 1822, at Sierra Leone. The general state of the atmosphere was as follows:—

"The day commenced as usual, calm and clear; between a quarter and half-past ten the sea-breeze sprung up from the N.W., freshened at noon from the W.N.W., accompanied by a diffused haze. At one, P.M., cleared, the wind still freshening. At two, some very light clouds in the zenith, which clearing away before three, it became hot and oppressive in the sun, the sea-breeze gradually declining towards evening, and the land-wind setting in at half-past nine."

TABLE XVIII. *Experiments upon Solar Radiation at Sierra Leone.*

March 2nd.								
Time.	No. 1.	No. 2.	Differ.	No. 3.	No. 4.	Differ.	No. 5.	Observations.
	°	°	°	°	°	°	°	
A.M. 10	79·3	95	15·7	110			70	
11	80	93	13	109			78	
12	80·2	91·5	11·3	105			82	Haze. [freshening.
P.M. 1	81·1	88	6·9	109	102	7	81	More clear, and wind
2	80·9	85	4·1	109·5	102	7·5	64	Light clouds.
3	83·4	91	7·6	118	107	11	70	Clear.
4	82·9	90	7·1	116	108	8	53	Wind dying away.
5	81·4	83·5	2·1	100	98	2		
5½	80	81·5	1·5	86	86	0		

Observations were made with the thermometers now described.

"No. I. The mean of two thermometers, one with a silvered, the other with a blackened bulb, (differing never more than two or three tenths of a degree), freely suspended in the thorough draft in a store-house with open doors and windows every way, and with a veranda around open at the sides.

"No. II. A thermometer with a blackened bulb, suspended freely between the pillars of a transit instrument (the instrument itself being removed), about one and a half feet above the earthen parapet of the fort, and several feet above the general level of the ground, in a fair exposure to the sun and wind.

"No. III. A similar thermometer to the preceding in the same exposure, but *in vacuo* in a glass case.

"No. IV. A thermometer in the same glass case with the preceding, but having its bulb inclosed in a double case of polished silver, not in contact with the glass or bulb.

"No. V. A differential thermometer *in vacuo;* the sentient ball coloured dark, and the other inclosed in a double case of polished silver. The graduation of this instrument was on the millesimal scale; *i. e.*, the interval between the boiling and freezing of water, divided into 1000°. The last three were only exposed at the time of observation, being removed intermediately into the house, when the equilibrium in the bulbs of No. V. was gradually restored at the tem-

perature indicated by No. I. These thermometers were registered, when the effect of the exposure had reached the maximum."

The same thermometers were employed on the 4th of March, the variations of the weather being as nearly similar as can be described—the usual weather, in short, of the season.

TABLE XIX. *Experiments upon Solar Radiation at Sierra Leone.*

March 4.							
Time.	No. 1.	No. 2.	Differ.	No. 3.	No. 4.	Differ.	No. 5.
A.M. 9	80°	95°	15°	110°	102°	8°	69°
10	80·5	93	12·5	110	105	5	79
11	80	94	14	110	105	5	86
12	80·2	98·5	18·3	115	108	7	93
P.M. 1	80·8	96	15·2	118	108	10	88
2	81	97	16	118	110	8	77
3	83	90·5	7·5	113	105	8	69
4	82·5	89·5	7	109·5	102	7·5	59

The first and most striking result of these observations, is the very small comparative energy of the solar rays. All the means adopted to measure their effect concur in this conclusion. The utmost difference between a blackened thermometer in the sun and another in the shade was only 18·3°; and *in vacuo*, of one prepared to repel the radiant heat, and of another to absorb it, 11°. It is obvious that the whole difference between the first and third thermometer cannot be ascribed to radiation, for the latter, although placed in a rarefied medium, was still surrounded by atte-

nuated air and aqueous vapour, the latter of which appeared in a pretty copious precipitation of moisture upon the sides of the glass. This atmosphere, however rare, was liable to become considerably heated under confinement. But even the maximum of this difference is only 38°.

The next series of experiments, which were made at Bahia, on the coast of Brazil, come into more immediate comparison with my own, and agree in the conclusion of the diminution of the force of radiation from a tropical sun. A mercurial register thermometer, having its bulb blackened and covered with black wool, was fully exposed to the sun on grass, and compared with a thermometer in the shade: the following Table exhibits the results.

TABLE XX. *Experiments upon Solar Radiation at Bahia.*

	Sun.	Shade.	Difference.
July 24	114°	82°	32°
„ 25	123	82	41
„ 26	124	83	41
„ 27	123	83	40
„ 28	95	78	17
„ 29	115	78	37
„ 30	127	80	47

Here the maximum effect was only 47°, with a nearly vertical sun; while the same influence, in our temperate climate in June, *in a medium not much less heated*, was 65°.

Colonel Sabine instituted a third set of experiments, upon the same point, during his stay in the Island of Jamaica.

The thermometer, with black wool, was exposed to the sun on the vegetation by which Port Royal is surrounded. It is a tongue of sand, projecting a considerable distance into the sea, and overrun by the Tibullus Maximus, which was at the time in flower. The ball of the thermometer was in contact with the vegetation, and supported by it about ten inches off the ground.

TABLE XXI. *Experiments upon Solar Radiation at Jamaica.*

	Sun.	Shade.	Difference.
	°	°	°
Aug. 25	122	86	36
26	123	87	36
27	122	86	36
28	122	86	36
29	123	86·5	36·5
30	123	86·5	36.5

A naked mercurial thermometer, suspended freely across between the upper branches of a stunted dead acacia, and exposed to the sun, near the other thermometer, about four and a half feet above the ground, and not in contact with the tree, carefully observed at intervals of the fore and afternoon, from the 25th to the 30th of October, was never seen to rise higher than 92°. This point it usually attained at 10 A.M., before the sea-breeze set in, fell as the breeze commenced, but attained about the same height in the afternoon, although the breeze had freshened intermediately.

The indications of the differential thermometer, before described *in vacuo*, were as follow:

TABLE XXII. *Experiments upon Solar Radiation at Jamaica.*

Date.	Hour.	Differential Thermometer.	OBSERVATIONS.
Oct. 24.	12	° 88	Strong breeze—perfectly clear.
	P.M. 1½	88	Ditto ditto.
26	A.M. 9½	82	No breeze—very clear.
	12	88	Fresh sea breeze—in 2 minutes.
29	12	90	Clear—little breeze—in 2 minutes.
	P.M. 2	86	Ditto—more breeze—in 2 minutes.
30	A.M. 10	88	Very clear—no breeze—in 2 min.
	P.M. ½	91	Very strong sea breeze—in 2 min.
	3½	74	Very strong breeze—in 2 min.
Nov. 3	A.M. 8	68	Calm and clear.
	9	82	Ditto ditto.
7	A.M. 7	48	Ditto ditto.

The smallness of the effect is no less striking from these results than from the last.

In looking over the interesting personal narrative of M. de Humboldt, (in which the inquirer, upon almost any subject, is sure to meet with valuable information) I find ample confirmation of these observations. At Cumana he remarks, "I have often endeavoured to measure *the power of the sun*, by two thermometers of mercury perfectly equal, one of which remained exposed to the sun, while the other was placed in the shade. The difference resulting from the absorption of the rays in the ball of the instrument *never* exceeded 3°·7 (6°·6 Fahr.) Sometimes it did not even rise higher than one or two degrees*."

A fourth set of Colonel Sabine's experiments, in the mountains of Jamaica, presents a comparison of the

* HUMBOLDT'S *Travels*, by H. M. Williams, vol. ii. p. 58.

greatest interest. The observations were made on the 31st of October, at Mr. Chisholm's house, situated on the summit of the Port Royal ridge, 4000 feet above the sea. The woolled thermometer was laid upon the grass-plat, about 100 yards from the house, and fairly exposed to the sun. In the forenoon, in intervals of the breeze, when the sky was clear, it rose above 130°; the thermometer in the shade, at the time, being 73°. The difference of 57° exhibits a much greater intensity of action than any that had been obtained at the level of the sea. The following observations of the differential thermometer *in vacuo*, in the same situation, confirm the conclusion.

TABLE XXIII. *Experiments upon Solar Radiation, upon the Mountains of Jamaica.*

Date.	Time.	Differential Thermometer.	Observations.
Oct. 31.	A.M. 9	° 74	Maximum produced in 1½ Minute.
	10	100	1½ Minute.
	11	84	1½ Minute, light clouds.
	12	100	1½ Minute, very clear.

As it appears, I think, incontrovertible, from a comparison of Colonel Sabine's experiments with my own, that the force of the sun's direct radiation decreases in approaching the equator, I became anxious to ascertain, if possible, whether an analogous contrary effect were observable in advancing towards the pole. In looking over the *Journal* of the late Expedition for the discovery of a north-west passage, I found some observations, which tended much to establish this

curious fact. At page 157 of that interesting narrative, Captain Parry observes:—"On the 16th (March), there being little wind, the weather was again pleasant and comfortable, though the thermometer remained very low. While it continued nearly calm, we observed the following differences in the temperature of the air in the shade, and in the sun; the latter were, however, noted by a thermometer placed under the ship's stern, which situation was a warm one, for the reasons before assigned." The difference of warmth in this situation had been before ascertained not to exceed from 2° to 5°.

TABLE XXIV. *Experiments upon Solar Radiation at Melville Island.*

Date.	Time.	Sun.	Shade.	Difference.
March 16	A.M. 9	+ 24°	− 24°	48°
	10	+ 27	− 23	50
	11	+ 28½	− 22	50½
	12	+ 29	− 21	50
	P.M. 3	+ 19	− 13	32

Again, on the 25th of March, the thermometer in the sun being placed *at a distance from the ship*, and the weather very fine and calm.

TABLE XXV. *Experiments upon Solar Radiation at Melville Island.*

Date.	Time.	Sun.	Shade.	Difference.
March 25	12	+ 30°	− 25°	55°
	P.M. 1	+ 17	− 22	39
	2	+ 25	− 22	47
	3	+ 21	− 22	43

Here it is seen that the sun had power to raise a thermometer, *which had not been prepared to receive its greatest impression,* 55° in the month of March, at Melville Island; the maximum effect in the vicinity of London, in the same month, *upon a thermometer covered with black wool,* being only 49°.

In Captain Scoresby's *Account of the Arctic Regions*, there are also many remarks which powerfully confirm the same opinion. "The force of the sun's rays," he observes, "is sometimes remarkable. Where they fall upon the snow-clad surface of the ice or land, they are, in a great measure, reflected, without producing any material elevation of temperature; but when they impinge on the black exterior of a ship, *the pitch on one side occasionally becomes fluid, while ice is rapidly generated at the other;* or, while a thermometer placed against the black paint-work, on which the sun shines, indicates a temperature of 80° or 90°, or *even more,* on the opposite side of the ship, a cold of 20° is sometimes found to prevail. This remarkable force of the sun's rays is accompanied with a corresponding intensity of light*."

To ascertain with precision the temperature denoted in the above extract, by the pitch becoming fluid, which appears to me to furnish the best measure of the force of the sun's rays, I tried the following experiment. I covered the bulb of a thermometer with pitch to the thickness of about $\frac{1}{10}$ of an inch, and suffered it to remain till it had become quite hard.

* Vol. i. p. 378.

I then held it at some distance from a fire, and noted the following points. At 100° Fahr., it began to soften. At 110° it was so soft it might be moulded into any form; from 120° to 136°, it rapidly approached fluidity, and, at the latter temperature dropped off the ball. The degree denoted cannot, therefore, be placed lower than 120°: and if ice were forming at the same time in the shade, the force of the sun's radiation could not be less than 90°.

In the account of Captain Scoresby's last voyage to Greenland, a direct experiment in latitude 80° 19′, confirms the same conclusion.

"The sun broke through the clouds, and produced a powerful effect upon the temperature. At two, A.M., the thermometer was 3° or 4° below zero. At eight, A.M., it was + 6°, and at ten, A.M., about + 14° in the shade. But the genial influence of the sun was still more striking. In a sheltered air, it produced the feeling of warmth; the black paint-work of the side of the ship, on which the sun shone, was heated to a temperature of 90° or 100°, and the pitch about the bends became fluid. Thus, while on one side was uncommon warmth, on the opposite side was intense freezing*." The radiating force of the sun must, therefore, have been 80 in the month of April.

The following additional fact, extracted from Captain Lyon's interesting *Journal*, is of the same nature as those already recorded in high latitudes; the place of observation and the date are, Igloolik, 16th Feb-

* *Journal of a Voyage to the Northern Whale Fishery*, p. 34.

ruary:—"I observed, even while the temperature in the shade was 35° below zero, that fine powder of snow melted under the influence of the sun when sprinkled on a stick covered with soot; thus making a difference of temperature existing at the same time as great as 67° and upwards*."

Here the coating of soot renders the experiment very closely comparable with a thermometer covered with black wool, with which the utmost effect I ever obtained, in the month of February, in this country, was 36°. The difference, therefore, in the two situations was 31°.

The Baron de Humboldt, on the other hand, "*often* endeavoured to measure *the power of the sun* between the tropics, by two thermometers of mercury perfectly equal, one of which remained exposed to the sun, while the other was placed in the shade. The difference resulting from the absorption of the rays in the ball of the instrument *never* exceeded 3°·7 (6°·6 Fahr.); *sometimes* it did not even rise higher than one or two degrees."

Colonel Sabine tried the very same experiment with a naked thermometer at Jamaica, and obtained the same result, namely, 3·1 centigrade degrees between the sun and the shade.

By reference to the Ephemerides of the Meteorological Society of the Palatinate, published in 1783 and following years, will be found a register of the power of the sun at Mannheim, measured by equal and carefully-adjusted thermometers, with naked bulbs,

* Lyon's *Journal*, p. 389.

nearly every day in the year for several years. It will there be seen that a difference of from 5 to 7 octogesimal degrees (11·3 to 15°·8 Fahr.) is often recorded.

The Baron de Humboldt has also recorded that he placed "the thermometer in the shade, in an airy spot, far from the reflection of the soil, at the Faubourg of the Guayqueries Indians. Cumana being regarded as one of the hottest, driest, and healthiest places of the low regions of equinoctial America, it is important to make known these partial observations. I take them by chance out of 1600 I possess. They will serve, above all, to certify that the climate of the tropics is much more characterized by the *duration of the heat*, than by its *intensity*, that is, by the *maxima* of temperature which the thermometer attains on certain days. I never saw that instrument at Cumana below 20°·8, *nor above* 32° 8 *cent.* (69·4 and 91·01 Fahr.): and I found on the registers of M. Orta, whose thermometers were compared by mine with those of the Observatory at Paris, that at Vera Cruz the maximum of heat in thirteen years *had only three times attained* 32° *cent.* (89·6 F.), *and once* 35°·7 (96·2 F.); *while we have seen the centesimal thermometer at Paris at* 38°·4*." (101·1 F.).

That this difference is accompanied by some difference in the quality of the radiant heat in the higher and lower latitudes, is rendered probable by an observation of Mr. Andrew Knight, well known for his admirable and practical remarks upon the physiology

* HUMBOLDT's *Personal Narrative*, translated by H. M. Williams, vol. vi. part ii. p. 779.

of the vegetable kingdom, who observed that pine-apples, ripened in the house during the winter, have proved of great excellence. He suggests that this fruit will ripen better early in the spring than in the summer months: "for," he says, "this species of plant, though extremely patient of a high temperature, is not by any means so patient of the action of very continued bright light as many other plants, and much less so than the fig and orange tree: possibly, having been formed by nature for intertropical climates, its powers of life may become fatigued and exhausted by the length of a bright English summer's day in high temperature*."

With respect to the greater energy of the solar rays upon the summit of a mountain than upon a plain, I find that Monsieur de Saussure made some decisive experiments which establish the same fact. In his *Voyages dans les Alpes*, the following observations occur:—"Je cherchais à Génève un verre ardent assez petit pour qu'il n'eut précisément que la force nécessaire pour allumer de l'amadou. Je portai en suite la même verre et le même amadou sur le haut de Salève et je le vis là produire le même effet que dans la plaine *et même avec plus de promptitude*†."

"Sur la cime du Cramont (777 French toises = 4967 English feet above the plain) un thermomètre appliqué sur le liège noirci, exposé directement aux rayons du soleil pendant un heure précise, c'est à dire, depuis 2^h 12′ jusques à 3^h 12′, (le 16 Juillet 1774,) étoit mouté à 21°, (79° Fahr.,) et un autre ther-

* *Hort. Trans.*, vol. iv. p. 548. † Tome ii. p. 363.

momètre, à boule nue, exposé en plein air aux rayons du soleil, à 4 pieds au-dessus du gazon, ne se soutenoit qu'à 5 degrés (43 Fahr.); le lendemain, de retour à Courmayeur, oú j'eus le bonheur d'avoir un tems clair, parfaitement semblable à celui de la veille, je choisis un prairie découverte dans laquelle j'établis mon appareil : le thermomètre placé sur le liège noirci montât dans dans un heure précise à 27°, (93° Fahr.,) et celui qui étoit en plein air à 19°, (75° Fahr.)*"

The same accurate observer also found, by comparative trials, that the chemical energy of the solar light, as well as its heating power, was much greater upon the summit of the Col du Géant than on the plain of Geneva.

From these facts, then, I conclude that the power of solar radiation in the atmosphere increases from the equator to the poles, and from below, upwards. The obstruction which the air offers to the passage of the rays is not alone dependent upon its density at the surface of the earth, for most of the experiments which establish the difference between the lower and the higher latitudes, were made under nearly equal heights of the barometer.

For the same reason the difference cannot be ascribed to any change in the cooling power of the medium, for MM. Dulong and Petit have established, from experiment, that the velocity of cooling, in any gas, where it is solely owing to contact, remains the same, if the density and the temperature of the gas change in such a way that the elasticity remains

* Tome ii. p. 365.

constant. Part of the difference, upon the summit of the mountain, may be traced to the diminution of elasticity, but no such cause operated (or, if it did, in a degree too small for appreciation) in the experiments upon the plains.

Having traced some of the modifications to which radiant caloric is subject in its passage from the sun to the earth, and having shewn the importance of a further developement both of the cause and its effects, I shall now endeavour to collect and combine some particulars with respect to the radiation of heat from the surface of the earth into space; a process, in which the welfare of the vegetable kingdom is no less concerned than in that which we have just been considering. My journal of observations contains a column, also, of the results of experiment upon this division of the subject; they are complete for nearly the whole of the three years. They were obtained by exposing, upon short grass, a register thermometer to an open aspect of the sky, having its bulb covered with black wool. The lowest depression, during the night, was entered in the register. The theory and practice of this experiment have been so clearly elucidated in Dr. Wells's *Essay*, that I can have nothing to add upon the subject: my only aim is to carry a little further the observation of a principle, which, from limited experience, but with a masterly hand, he has shown to be of such vast importance. The following Table exhibits the mean effect of radiation for every month, deduced from the averages of the three years, together with its greatest observed intensity in the same intervals. The first column shows the month,

the second the minimum temperature of the air, the third the mean effect, and the fourth the maximum force of radiation:—

TABLE XXVI. *Shewing the Mean Minimum Temperature of the Air, with the Mean and Maximum Force of Terrestrial Radiation, for every Month of the Year.*

	Mean Minimum of the Air.	Mean Depression from Radiation.	Maximum Depression from Radiation.
January . . .	32°6	3°5	10°
February . .	33·7	4·7	10
March . . .	37·7	5·5	10
April	42·2	6·2	14
May . . .	45·1	4·2	13
June . . .	48·1	5·2	17
July	52·2	3·6	13
August . . .	52·9	5·2	12
September . .	50·1	5·4	13
October . .	42·1	4·8	11
November . .	38·3	3·6	10
December . .	35·4	3·5	11

In the last column we may observe an approximation to the law of radiation, established by the experiments of MM. Dulong and Petit; namely, that the velocity of cooling *in vacuo* (or force of radiation) increases as the terms of a geometrical progression, for excess of temperature in arithmetical progression. The power of radiation, as exhibited in the Table, has evidently a tendency to increase with the heat, although the effect is masked by too many disturbing causes to have enabled us to discover the law of its progression. The amount of effect denoted in the third column is principally dependant upon the clear-

ness of the atmosphere, and it affords no bad estimate of the comparative brightness of the different months. April appears to be the clearest month of the year, and the cloudy state of July in the midst of summer is very remarkable.

From the particulars of the diary it will be found, that vegetation is liable to be affected at night, from the influence of radiation, by a temperature below the freezing point of water ten months in the year; and that even in the two months, July and August, the only exceptions, the radiant thermometer sometimes falls to 35°.

The comparative experiments of Colonel Sabine between the tropics are as follows:—

At Bahia he exposed upon grass to the aspect of the sky, an alcohol thermometer, registering the extreme cold, and having its bulb covered with black wool. The following is the comparison between its indications and those of a register thermometer placed under shelter.

TABLE XXVII. *Experiments upon Terrestrial Radiation at Bahia.*

	Temperature of Air.	Temperature of Radiation.	Difference.	Observations.
July 24	68°	63·5°	4·5°	Dew.
25	68	63·5	4·5	Ditto.
26	72	62·5	9·5	Ditto.
27	70	61·	9·	Ditto.
28	64	60·5	3·5	
29	67	59·5	7·5	
30	65	64·	1·	

The register of cold was the same, whether the thermometer was placed on a grass-plat or on a thick bed of *Rotboëlia*, or on thick tufts of *Poa*.

At Jamaica, the radiating thermometer was placed in the manner before described, in contact with the vegetation, and supported by it about ten inches above the ground. The following are the results:—

TABLE XXVIII. *Experiments upon Terrestrial Radiation at Jamaica.*

		Temperature of Air.	Temperature of Radiation.	Difference.
October	25	76°	72°	4°
	26	76	69	7
	27	76	65	11
	28	76	66	10
	29	76·5	65	11·5
	30	76	65	11
November	3	76	67	9

On the mountains, at 4000 feet above the level of the sea, the thermometer, laid upon grass, afforded the following comparison:

TABLE XXIX. *Experiments upon Terrestrial Radiation upon the Mountains of Jamaica.*

Date.	Time.	Temp. of Air.	Temp. of Rad.	Difference.	OBSERVATIONS.
Oct. 31	P.M. 10	65°	51°	14°	Clear and calm.
Nov. 1	A.M. 5	63	45	18	Ditto ditto.
	P.M. 11	64	51	13	Clear and gentle breezes.
„ 2	A.M. 5	64	55	·9	Ditto ditto.

From all these experiments taken together, it would appear that the same cause which obstructs the

passage of radiant heat in the atmosphere from the sun, opposes also its transmission from the earth into space. The force of radiation for the given temperature is less between the tropics, than at the latitude of London; and it obviously increases as we ascend above the surface of the earth.

I have sought, unsuccessfully, for facts which might tend to throw any light upon the power of terrestrial radiation in the arctic regions; but the intense cold which was found to prevail, during calm weather, in Melville Island, so much beyond the amount of previous calculation, is a strong argument in favour of an increased effect.

In Captain Scoresby's *Journal*, the following account of the freezing of the sea while the temperature of the air was considerably above the point of congelation, must evidently be attributed to radiation of a very powerful degree.

"In cloudy weather, no freezing of the sea, I believe, ever occurs, when the temperature is above 29°; but in clear calm weather, the sea, in the interstices of the ice, generally freezes on the decline of the sun towards the meridian below the pole, though the temperature be 32°, or higher. In the instance now alluded to, the freezing commenced when the temperature was 36°, being 7½° or 8° above the freezing point of sea-water. About 2 A.M. the thermometer in the air fell to 33°, by which time the bay-ice was of such consistence that the headway of the ship, under a light breeze, was sometime stopped by it*."

* Scoresby's *Journal*, p. 291.

I shall now proceed to detail some further experiments which I have made at different times, the results of which may not prove unimportant to the general subject of radiation. The apparatus which I employed was a concave reflector of copper, plated with silver, of a parabolic form; its diameter was 6 inches, and the length of its focus 1¼ inches. Through a collar in its side a thermometer could be passed, and its bulb fixed in the focus, the scale being kept on the outside. This reflector was placed upon a foot with a ball and socket joint, that enabled it to turn in any direction.

Dr. Wollaston was the first to expose a concave metallic mirror, turned upwards to the free air, with a thermometer placed in its focus; and he found that the thermometer indicated a lower temperature after being thus exposed for a short time. This experiment was made before the publication of Dr. Wells's *Essay*, but it does not appear that Dr. Wollaston pursued the subject further. Sir J. Leslie, some years afterwards, adapted the differential thermometer to this idea, and contrived an instrument which he has called *an Æthrioscope*. This was nothing more than a metallic reflector, with one of the balls of a differential thermometer placed in the focus, and the other out of it. He confirmed Dr. Wollaston's result, and the thermometer fell, upon being exposed to a clear sky. The effect he found to depend upon the clearness of the atmosphere.

Sir J. Leslie, in his description of the construction and uses of his Æthrioscope, has, unfortunately,

I think, indulged in a brilliancy of imagination and figurativeness of language, which have greatly obscured his meaning. He ascribes, for instance, the action of the instrument to "cold pulses showered entire from the heavens." He speaks of "the higher strata of the atmosphere darting cold pulses downwards, and the lower strata projecting equal pulses of heat upwards."

The Æthrioscope, he says, "extends its sensation through indefinite space, and reveals the condition of the remotest atmosphere." Nay, more, he expects that "when constructed with greater delicacy, it may, perhaps, scent the distant winds, and detect the actual temperature of different portions of the heavens." With far humbler views I have made considerable use of Dr. Wollaston's apparatus, which, for reasons which I shall not now stop to discuss, I very much prefer to Sir J. Leslie's. The standard thermometer, to which all my observations refer, when not otherwise expressed, had its bulb covered with black wool.

My first object was to ascertain the force of radiation from a thermometer, so guarded from the influence of surrounding bodies, compared with another, exposed, as I have before described, upon grass. The following Table exhibits the results. The first column shows the lowest temperature of the air during the night, the second the lowest temperature of a thermometer on grass, and the third that of the thermometer in the reflector.

TABLE XXX. *Comparison of the Force of Radiation in a Reflector and on the Grass.*

Temp. of Air.	Temp. of Grass.	Temp. in Reflector.	OBSERVATIONS.
° 42	° 34	° 30	Very fine and clear.
47	39	35	Ditto ditto.
52	44	42	Ditto ditto.
44	35	32	Ditto ditto.
44	36	34	Ditto ditto.
54	48	45	Ditto ditto.
58	52	52	Dull.
57	51	49	Very fine—moon hazy.
56	51	50	Light clouds.
51	41	41	Very fine and clear.
45	35	35	Ditto ditto.
50	42	41	Ditto ditto.
50	42·3	40·5	Mean.

The average difference is not quite two degrees.

I consider this as much the most accurate method of measuring the force of terrestrial radiation: at the same time it is gratifying to find that the means which I had adopted, before this idea had occurred to me, were not, upon a mean of observations, liable to any very considerable error. The radiant thermometer is so completely insulated by the reflector, from the counter-radiation of surrounding bodies, that it may be applied with equal effect in any situation where the aspect of the sky is very limited. Even in the streets of London, where the radiation of an exposed thermometer is nearly neutralized, and the utmost effect never exceeds two or three degrees, that of the thermometer, guarded by the reflector, is wholly unim-

peded. Experiments that are thus made, in whatever situation, are strictly comparable, provided they are screened from any strong action of the wind.

Being thus in possession of the means of cutting off the access of radiant matter from any source, and of directing it to any required object, I was anxious to ascertain the force with which it was given off while the sun was above the horizon, compared with what it was in the absence of that luminary. Under the most favourable circumstances, when the air was calm and the atmosphere clear, I never could obtain an effect of more than five or six degrees with the thermometer covered with black wool. It then occurred to me, to try the influence of colour in modifying the results. I had another reflector made exactly similar to the former, and their power, upon trial, was found to be precisely equal; that is to say, the radiating thermometer fell to an equal amount in each of them. I now covered the ball of a thermometer with white wool, and placed it in the focus of one reflector, and the thermometer with black wool in the focus of the other. I selected a cloudless day for the experiment, and placed the two instruments, side by side, in the shade of a tree, inclining them at equal angles towards the clear eastern sky. The following Table includes the results.

TABLE XXXI. *Comparison of the Force of Radiation from Black and White Wool.*

May 16.	Radiation from Black Wool.	Radiation from White Wool.	Temp. of Air.	OBSERVATIONS.
P.M. $3\frac{1}{2}$	58°	53°	63°	Atmos. cloudless.
4	58	53	63	During the experiment the reflectors were changed.
8	44	43	54	
11	36	36	47	
During Night	35	35	45	

The amount of radiation, therefore, from the white wool, was equal, during the time the sun was high in the heavens, to what it was during the night; while it was one-half less from the black wool. During the absence of the sun, the radiating power of the two was equal.

The experiment was repeated under varying circumstances; and in examining the results, as included in the following Table, it will be necessary to attend particularly to the collateral circumstances.

TABLE XXXII. *Comparison of the Force of Radiation in Black and White Wool.*

May 17.	Radiation from Black Wool.	Radiation from White Wool.	Temp. of Air.	OBSERVATIONS.
P.M. $1\frac{1}{2}$	64°	59°	65°	Overcast, with cumulo-stratus.
2	68	60	65	Clearing—reflectors turned to clearing space.
$2\frac{1}{2}$	73	62	65	Faint sunshine.
$3\frac{1}{2}$	74	62	66	Strong sunshine—reflectors turned, so that the shadows of the bulbs just appeared on the metal.
4	76	64	68	
11	51	51	55	Lightly overcast.
Night.	42	42	51	Fine.

The power of radiation was nearly neutralized in the black wool, while the sky was overcast, but in the white wool was only reduced to about one-half. As the sky cleared, the reflectors being turned towards the sun's place, the black thermometer rose above the temperature of the air, and the white thermometer still gave off more heat than it received. In full sun-shine, the reflectors being just turned out of the direct rays, the black thermometer rose 8° above the temperature of the air, and the white thermometer fell 4° below it. In estimating these effects it must be remembered, that the action of the reflector, in receiving and transmitting heat, is different. In the former case, we have an exaggerated action; the heat which falls upon the surface of the speculum is thrown upon the thermometer in a concentrated form. In the latter case, the heat, which radiates from the thermometer in the focus, falls upon the concave metal, and is reflected into space in parallel lines. The effect is, therefore, only slightly augmented from the larger aspect of the sky. Whenever the reflector, with the black-wooled thermometer, is turned, while the sun is above the horizon, towards a cloud, the mercury rises above the temperature of the air, excepting in the winter months; and a distinct effect is produced even from the quarter most distant from the sun. The concrete vapour seems to disperse the radiant matter, and to act upon it in much the same way as ground glass upon transmitted light. I subjoin some experiments which illustrate this point, and show the effect of two similar thermometers in similar reflectors, directed to different quarters of the heavens.

Table XXXIII. *Effects of Radiation under different Aspects of the Sky.*

Date.	Hour.	Position of the Reflector.	Temp. of Black Wool.	Temp. of Air.	Observations.
July 2	12	Horizontal Inclined 30°	76° 79	63°	Sky overcast—cumulo-stratus—sun's place not visible—and brisk wind from S.W.
	1	Horizontal Inclined 30°	83 83	63	Sun's place just visible, but no shadows.
	2	Horizontal Inclined 30°	86 86	63	Ditto ditto.
	2½	Horizontal Inclined E. 30°	83 82	63	Sun's place not visible.
	3	Horizontal Inclined N. 30°	79 79	63	Ditto ditto.
		Inclined N. 30° S. 30	76 79	63	Ditto ditto.
		Inclined N.E. 30° S.W. 30°	85 88	63	Ditto ditto
	3½	Inclined N.E. 30° S.W. 30°	96 100	63	
		Inclined W. E.	55 55	61	Just before sunset.
	11 P.M.	Inclined N. S.	57 57	61	
	Night.	Inclined N. E.	40 40	48	Fine.
July 4	All Night.	Horizontal Vertical	41 43	51	Very fine.

No effect is produced by any cloud after the sun has sunk below the horizon; and in an overcast night

the action of radiation is perfectly neutralized. I have appended to this Essay a series of observations made in London, at different hours of the night and day, from January to April, 1822.

As the power in different bodies of absorbing heat, and the power of emitting it, do not appear to be equal under every circumstance, as has been demonstrated in the case of the black and the white wool, it becomes a curious inquiry to ascertain the relation of various substances to these effects. I regret that I have not had leisure to pursue this branch of the subject with the attention which it deserves. I shall subjoin the results of two or three experiments, to shew that much curious information might be expected from the investigation.

TABLE XXXIV. *Comparison of the Force of Radiation from different Substances.*

		Substance compared.	Radiation.	Black Wool.	Temp. of Air.	OBSERVATIONS.
			°	°	°	
May 21	11 P.M.	Naked Alcohol Therm.	48	46	55	Very fine night.
	Night	....	40	38	48	
22	9 A.M.	....	53	58	56	Haze.
23	8 P.M.	Garden mould.	41	38	46	Very fine.
	11	....	40	37	46	Ditto
	Night	....	38	35	45	Ditto
24	9 A.M.	....	59	59	56	Ditto
	8 P.M.	Chalk.	46	43	53	Ditto
	11	....	43	40	50	Ditto
	Night	....	35	33	44	Ditto
25	A.M. 11	....	67	61	62	Lightly over-cast.
18	P.M. 11	Leaf of the Rose Campion.	46	45	57	Very fine.
19	P.M. 8	....	51	50	61	Ditto
	11	....	44	43	53	Ditto
	Night.	....	39	38	48	Ditto
22	P.M. 11	Integument of the flower of an Iris.	44	42	52	Ditto
	Night.	....	38	37	47	Ditto

The standard of comparison was, in all cases, the black-wooled thermometer, and the substance compared was stuck upon a thermometer, in a similar reflector, by its side.

Whilst engaged in this course of experiment, it occurred to me that a favourable opportunity presented itself of determining a question which has at different times occasioned considerable controversy, and concerning which, many discordant statements have often been made: I mean the radiation of heat from the body of the moon. Dr. Howard has published the following result of an experiment by means of a delicate differential thermometer, which seems to establish the reality of such an effect.

"Having blackened the upper ball of my differential thermometer, I placed it in the focus of a thirteen-inch reflecting mirror, which was opposed to the light of a bright full-moon. The liquid began immediately to sink, and in half a minute was depressed 8°, where it became stationary. On placing a screen between the mirror and the moon, it rose again to the same level, and was again depressed on removing this obstacle*."

The above extract does not clearly explain in which leg of the instrument the depression of the liquid took place; and the effect, *as described*, might just as well be attributed to the radiation of heat from the blackened ball of the thermometer, as to radiation to it from the moon. To determine this doubt, I tried the following experiments:—

* SILLIMAN'S *Journal*, vol. ii. p. 329.

I selected an unexceptionable opportunity, 26th of December, 1822. The moon was in that part of her orbit when she is nearest to the earth, and was approaching to the full. The atmosphere was cloudless, and perfectly calm. The smallest writing was distinctly legible in the moonlight. At 9 P.M. the temperature of the air was 28°. I placed the black thermometer in the focus of the reflector, and directed it to a part of the sky at a distance from the moon. In a few minutes it fell to 20°, and was stationary. I then turned it immediately towards the moon, and caused the focus of light to fall upon the ball of the thermometer. It still remained stationary at 20°, and for half an hour, during which the rays were concentrated upon it, the mercury never moved.

At 11 P.M. the temperature of the air . . .	27°
reflector turned from the moon	19°
——— in the moon-beams .	19°

Dec. 28th, 7 P.M.

Moon full—atmosphere perfectly calm and clear.

Temperature of the air	24°
Reflector turned from the moon	15°
——— in the moon-beams	15°

At 11 P.M. the sky became lightly clouded, and the amount of radiation was only 2°.

Temperature of air	22°
Radiating thermometer	20°

Thus it appears that, so far from possessing the power of radiating heat to the surface of the earth, the moon does not even diminish the amount of radiation from the earth; and the lightest vapour is more efficacious in this respect than the concentrated influ-

ence of the lunar light. Similar results have since been obtained by M. Melloni.

TABLE XXXV. *Observations of a Black Radiating Thermometer in a Concave Reflector.*

Turned to the North, Angle 30°.

Date.	Hour.	Temp. of the Air.	Day.	Night.	Difference.	State of Reflector.	State of Weather.
1822.		°	°	°	°		
Jan. 13	p.m. 4	48	45	....	− 3	....	Fine, but misty
	11	45	....	37	− 8	....	Ditto ditto
	night	40	....	32	− 8	....	Very fine
14	a.m. 10	42	35	....	− 7	Spots of rain	Very fine and clear
	p.m. 4	42	35	....	− 7	....	Cloudless
	11	39	....	30	− 9	....	Light clouds
	night	40	....	36	− 4	....	Ditto ditto
15	a.m. 9	40	32	....	− 8	Bright	Very clear
	p.m. 11	31	....	21	−10	....	Ditto ditto
	night	30	....	20	−10	Bright	Ditto ditto
16	a.m. 9	31	22	....	− 9	....	Ditto ditto
	p.m. 4	31	21	....	−10	....	Ditto ditto
	11	29	....	19	−10	....	Ditto ditto
	night	29	....	19	−10	....	Ditto ditto
17	a.m. 9	33	33	....	0	....	Snow
	p.m. 11	33	....	26	− 7	....	Very fine
	night	32	....	25	− 7	....	Ditto ditto
18	a.m. 9	35	30	....	− 5	Bright	Ditto ditto misty
	p.m. 4	39	34	....	− 5	....	Ditto ditto ditto
	11	39	....	37	− 2	....	Overcast and dull
	night	38	....	33	− 5	....	Dull
19	a.m. 9	41	41	....	0	Tarnished	Dull and foggy
26	a.m. 9	40	32	....	− 8	....	Very fine
	p.m. 11	40	....	35	− 5	....	Dull
	night	32	....	22	−10	Dull and spotted	Very fine
27	a.m. 10	34	27	....	− 7	....	Ditto ditto
	p.m. 4	47	47	....	0	....	Overcast and dull
	11	[illegible]	....	40	0	....	Ditto ditto
	night	35	....	33	− 2	....	Dull
28	a.m. 9	45	43	....	− 2	Spotted with rain	Mild and misty
	p.m. 11	41	....	39	− 2	....	Overcast and dull
	night	35	....	27	− 8	....	Very fine but misty
29	a.m. 9	37	31	....	− 6	Blacks in the mirror	Ditto ditto
	p.m. 11	38	....	34	− 4	....	Lightly overcast
	night	32	....	22	−10	....	Very fine
30	a.m. 9	34	26	....	− 8	....	Ditto ditto

TABLE XXXV. *continued.*

Date.	Hour.	Temp. of the Air.	Day.	Night.	Difference.	State of Reflector.	State of Weather.
1822.		°	°	°	°		
Jan. 30	p.m. 11	34	....	30	− 4	....	Fog
	night	30	....	23	− 7	....	Fine
31	a.m. 9	35	33	....	− 2	Dew upon lower half	Light clouds
	p.m. 11	35	....	28	− 7	....	Drops of rain
	night	35	....	28	− 7	....	Fine
Feb. 1	a.m. 9	42	37	....	− 5	Spotted with rain	Very fine
	p.m. 11	38	..	29	− 9	....	Ditto ditto
2	a.m. 9	47	47	....	0	Tarnished & spotted	Small rain
	p.m. 11	49	....	45	− 4	....	Fine
	night	39	....	39	0	Full of rain	Rain
3	a.m. 10	44	39	....	− 5	....	Very fine
	p.m. 11	37	....	28	− 9	....	Ditto ditto
	night	33	....	25	− 8	....	Ditto ditto
4	a.m. 9	38	36	....	− 2	Moisture running off the bulb	Foggy
	p.m. 11	47	....	45	− 2	....	Overcast
	night	38	...	37	− 1	....	Stormy
5	a.m. 10	49	42	....	− 7	....	Fine
	p.m. 11	39	....	30	− 9	....	Very fine
	night	32	....	22	−10	Hoar-frost upon the bulb and stem	Ditto ditto
6	a.m. 10	35	27	....	− 8	....	Ditto ditto
	p.m. 11½	41	....	35	− 6	....	Dull and close
7	a.m. 9	45	43	....	− 2	Tarnished	Ditto ditto
	p.m. 3	48	45	....	− 3	....	Ditto ditto
	11	47	....	43	− 4	....	Ditto ditto
	night	45	....	41	− 4	Full of rain	Ditto ditto
8	a.m. 9	48	45	....	− 3	....	Overcast but fine
	p.m. 11	45	....	42	− 3	....	Ditto ditto
	night	42	....	36	− 6	Spotted with rain	Ditto ditto.
9	a.m. 10	47	47	....	0	....	Overcast and mild
	p.m. 11	49	....	47	− 2	....	Ditto ditto
	night	46	....	41	− 5	....	Ditto ditto
10	a.m. 10	47	45	....	− 2	....	Ditto ditto
	p.m. 11	47	....	45	− 2	....	Light rain
	night	41	...	33	− 8	Spotted with rain	Very fine
11	a.m. 10	44	41	...	− 3	....	Ditto ditto
12	p.m. 11	39	....	36	− 3	Stained	Fog
	night	37	....	33	− 4	Some water	Ditto
13	a.m. 9	41	38	....	− 3	....	Fine but misty
	p.m. 4	44	38	....	− 6	....	Ditto ditto
	night	40	....	32	− 8	....	Very fine
24	a.m. 10	46	48	....	+ 2	....	Lightly overcast
	p.m. 11	48	....	46	− 2	....	Overcast and dull
	night	46	....	43	− 3	....	Ditto ditto

TABLE XXXV. *continued.*

Date.	Hour.	Temp. of the Air.	Day.	Night.	Difference.	State of Reflector.	State of Weather.
1822. Feb. 25	a.m. 10	51	55	....	+ 4	....	Lightly overcast
	p.m. 11	47	....	43	− 4	....	Ditto ditto
	night	44	...	39	− 5	Bright	Ditto ditto
26	a.m. 10	49	53	....	+ 4	....	Ditto ditto
	p.m. 4	51	54	....	+ 3	....	Overcast, rain
	11	45	....	41	− 4	....	Clearing
	night	36	....	26	−10	Spotted with rain	Very fine
27	a.m. 10	42	34	....	− 8	....	Ditto ditto
	p.m. 11	35	....	24	−11	....	Ditto ditto
	night	31	....	22	− 9	Hoar-frost on bulb	Ditto ditto
28	a.m. 10	34	30	....	[illegible] 4	....	Ditto ditto, fog
	p.m. [illegible]	43	37	....	− 6	....	Very fine
	11	35	....	26	− 9	....	Ditto ditto
	night	30	....	20	−10	Hoar-frost on bulb	Ditto ditto
Mar. 1	a.m. 10	34	31	....	− 3	....	Ditto ditto, fog
	p.m. 11	39	....	33	− 6	....	Light clouds
	night	34	....	31	− 3	....	Ditto ditto
2	a.m. 10	46	47	...	+ 1	....	Overcast and mild
	p.m. 11	43	...	36	− 7	... ...	Very fine
11	p.m. 4	46	50	....	+ 4	....	Turned to a dense
	5	44	40	..	− 4	....	Very fine [cloud
	11	37	....	28	− 9	....	Ditto ditto
14	a.m. 10	54	60	....	+ 6	.	Overcast and dull
19	a.m. 10	56	61	....	+ 5	....	Lightly overcast
	5	59	57	....	− 2	.. ...	Ditto ditto
	11	54	....	51	− 3	... .	Ditto ditto
	night	51	....	46	− 5	....	Fine
20	a.m. 10	54	58	....	+ 4	... ..	Lightly overcast
	p.m. 5	56	50	....	− 6	....	Very fine
	night	46	....	37	− 9	... .	Ditto ditto
21	a.m. 10	51	52	....	+ 1	....	Overcast
	p.m. 5	56	51	....	− 5	... .	Very fine
	11	51	....	49	− 2	....	Overcast
	night	41	....	31	−10	.. ....	Very fine
27	a.m. 10	52	57	....	+ 5	....	Overcast
	p.m. 5	56	49	...	− 7	....	Very fine
	night	46	....	37	− [illegible]	....	Ditto ditto
April 1	a.m. 10	42	44	....	+ 2	....	Dense clouds
	p.m. 5	46	46	....	0	....	Overcast and dull
	11	42	....	32	−10	....	Very fine
	11½	43	....	39	− 4	....	Lightly overcast
	night	39	....	31	− 8	....	Fine
3	a.m. 10	50	59	....	+ 9	....	Lightly overcast
	p.m. 1	54	60	....	+ 6	....	Ditto ditto
	2	53	61	....	+ 8	....	Ditto ditto
	3	53	50	....	− 3	....	Clear

TABLE XXXV. *continued.*

Date.	Hour.	Temp. of the Air.	Day.	Night.	Difference.	State of Reflector.	State of Weather.
1822.							
April 3	p.m. 5	50	42	...	− 8	....	Very fine
	11	43	....	35	− 8	....	Ditto ditto
	night	40	....	31	− 9	....	Ditto ditto
4	a.m. 10	49	58	....	+ 9	....	Lightly overcast
	10½	51	61	...	+10	....	Ditto ditto
	11	51	62	....	+11	....	Ditto ditto
	12	51	60	....	+ 9	....	Ditto, drops of rain
	p.m. ½	52	64	....	+12	....	Ditto ditto
	1	52	58	....	+ 6	....	Ditto ditto
	3½	51	53	....	+ 2	....	Clearing
	5	49	47	....	− 2	....	Ditto
	11	47	...	42	− 5	....	Overcast
	night	43	....	34	− 9	....	Fine
5	a.m. 10	51	62	....	+11	....	Lightly overcast
	p.m. 5	51	50	....	− 1	....	Ditto ditto
	11	46	....	37	− 9	....	Very fine
	night	43	....	33	−10	....	Ditto ditto
6	a.m. 10	52	52	....	0	....	Ditto ditto
	p.m. 5	49	49	....	0	....	Ditto ditto
	11	41	....	31	−10	....	Ditto ditto
	night	39	....	30	− 9	....	Ditto ditto
7	a.m. 10	45	51	....	+ 6	....	Overcast
	night	36	....	27	− 9	....	Very fine
8	a.m. 10	45	46	....	+ 1	....	Ditto ditto
	p.m. 5	39	39	....	0	....	Hail showers
	night	35	....	30	− 5	....	Fine
15	a.m. 10	57	67	....	+10	....	Lightly overcast
16	p.m. 5	54	53	...	− 1	....	Dull
	11	46	....	37	− 9	....	Very fine
	night	41	...	34	− 7	....	Foggy
28	a.m. 10	56	67	....	+11	....	Very hazy
	night	46	....	40	− 6	....	Fine

Sir John Herschel has recently contrived an instrument, and devised a method of observation, the extended use of which will, it is to be hoped, afford accurate measures of many of the effects of solar radiation, which have only been hitherto roughly estimated in the manner above pointed out, and he has obligingly allowed me to make use of the description which he has himself drawn up of its construction, and of his method of using it.

The *Actinometer* may be described as a thermometer with a large cylindric bulb, containing a deep-blue fluid (the ammonio-sulphate of copper), and inclosed in a wooden case, blackened interiorly, and covered with a piece of thick plate glass. The capacity of the bulb may be caused to vary, by screwing in or out a plunger, which enters parallel to the axis of the cylinder, and the use of which is to retain the top of the column of liquid within the range of the tube, which is connected with the cylinder as in the common thermometer, and which it would otherwise be liable to exceed, owing to the great variations of temperature to which it is exposed. The *velocity* of heating during exposure to the sun is ascertained by limiting the exposure to *one minute*, during which the rise of the liquid is accurately observed. But since, during this minute, the rise was not that due to the solar influence alone, but to the direct solar influence *plus* or *minus* all the cooling or heating influences simultaneously acting upon the actinometer, these indirect influences are ascertained and allowed for by exposing the instrument for *one minute* behind a

screen, which merely stops the solar rays, but allows all other actions to go forward. If the instrumental readings *fall* during the shade observation (owing to the coolness of the atmosphere, and the high temperature of the liquid), it is plain that the solar action was not only to raise, but to *maintain* the temperature, and that the fall during the shade observation must be added to the rise during the sun observations, to give the effect due to the sun. On the other hand, if the temperature continue to rise during the shade observation, which may be due to heat indirectly reflected, or to the communication of heat from the parts of the instrument, it is plain that the rise in the sun was not wholly due to the immediate solar influence, and therefore that the rise in the shade must be subtracted from it.

To use the instrument, examine first whether there be any air in the cylinder, which is easily seen by holding it level, and tilting it, when the air, if any, will be seen to run along it. If there be any, hold it upright in the left hand, and the air will ascend to the root of the thermometer-tube. Then, by alternately screwing and unscrewing the screw with the right hand, as the case may require, it will always be practicable to drive the air out of the cylinder into the ball, and suck down liquid, if any, from the ball, to supply its place, till the air is entirely evacuated from the cylinder, and the latter, as well as the whole stem of the thermometer-tube, is full of the liquid in an unbroken column. Then, holding it horizontally, face upwards, slowly and cautiously unscrew the screw, till the liquid retreats to the zero of the scale.

The upper bulb is drawn out into a fine tube, which is stopped with wax. When it is needed to empty, cleanse, and refill the instrument, liquid must first be forced up into the ball, so as to compress the air in it. On warming the end, the wax will be forced out, and the screw being then totally unscrewed, and the liquid poured out, the interior of the instrument may be washed with water slightly acidulated, and the tube, ball, &c., cleansed, in the same way, after which the wax must be replaced, and the instrument refilled.

To make an observation with the actinometer, the observer must station himself in the sunshine, or in some sharply terminated shadow, so that without inconvenience, or materially altering his situation, or the exposure of the instrument in other respects, he can hold it at pleasure, either in full sun or total shadow. If placed in the sun, he must provide himself with a screen of pasteboard or tin plate, large enough to shade the whole of the lower part or chamber of the instrument, which should be placed not less than two feet from the instrument, and should be removeable in an instant of time. The best station is a room with closed doors, before an open window, or under an opening in the roof into which the sun shines freely. Draughts of air should be prevented as much as possible. If the observations be made out of doors, shelter from gusts of wind, and freedom from all penumbral shadows, as of ropes, rigging, branches, &c., should be sought. Generally, the more the observer is at his ease, with his watch and writing-table

beside him, the better. He should have a watch or chronometer beating at least twice in a second, and provided with a second hand; also a pencil and paper ruled, according to the form subjoined, for registering the observations. Let him then grasp the instrument in his left hand, or if he have a proper stand (which is preferable on shore or in a building*), otherwise firmly support it, so as to expose its face perpendicularly to the direct rays of the sun, as exactly as may be.

The liquid, as soon as exposed, will mount rapidly in the stem. It should be allowed to do so for three or four minutes before the observation begins, taking care, however, not to let it mount into the bulb, by a proper use of the screw. At the same time the tube should be carefully cleared (by the same action) of all small broken portions of liquid remaining in it, which should all be drawn down into the bulb. When all is ready for observation, draw the liquid down to zero of its scale, gently and steadily; place it on its stand, with its screen before it, and proceed as follows.

Having previously ascertained how many times (suppose 20) the watch beats in five seconds, let the screen be withdrawn at ten seconds before a complete minute shown by the watch, suppose at $2^h\ 14^m\ 50^s$. From 50^s to 55^s, say 0, 0, 0, ... at each beat of the watch, looking meanwhile that all is right. At 55^s complete, count 0, 1, 2, ... up to 20 beats, or to the

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* This may consist of two deal boards, 18 inches long, connected by a hinge, and kept at any required angle by an iron, pointed at each end. The upper should have a little rabbet or moulding fitting loosely round the actinometer, to prevent its slipping off.

whole minute, $2^h\ 15^m\ 0^s$, keeping the eye not on the watch, but on the end of the rising column of liquid. At the 20th beat read off, and register the reading (12°·0), as in column 3, A, of the annexed form. Then wait, watching the column of air above the liquid, to see that no blebs of liquid are in it, or at the opening of the upper bulb (which will cause the movement of the ascending column to be performed by starts), till the minute is nearly elapsed. At the 50th second begin to watch the liquid rising; at 55^s begin to count 0, 1, 2, up to 20 beats, as before, attentively watching the rise of the liquid; and at the 20th beat, or complete minute ($2^h\ 16^m\ 0^s$) read off and instantly shade the instrument, or withdraw it *just out* of the sun and penumbra. Then register the reading off (43°·3) in column 3, B, and prepare for the shade observation. All this may be done without hurry in 20 seconds, with time also to withdraw the screw if the end of the column be inconveniently high in the scale, which is often required. At the 20th second prepare to observe; at the 25th begin to count beats, 0, 1, 2, ... 20; and at the 20th beat, *i. e.*, at $2^h\ 16^m\ 30^s$, read off, and enter the reading in column 3, A, as the initial shade reading (45°·2). Then wait as before till nearly a minute has elapsed, and at $2^h\ 17^m\ 20^s$ again prepare. At $17^m\ 25^s$ begin to count beats; at $17^m\ 30^s$ read off, and enter this *terminal* shade reading (42°·8) in column 3, B, and if needed, withdraw the zero.

Again wait 20^s, in which interval there is time for the entry, &c. At $17^m\ 50^s$ remove the screen, or

expose the instrument in the sun; at 55^s begin to count beats; and at the complete minute, $18^m\ 0^s$, read off ($14°·8$), and so on for several alternations, *taking care to begin and end each series with a sun observation.* If the instrument be held in the hand, care should be taken not to change the inclination of its axis to the horizon between the readings, or the compressibility of the liquid by its own weight will produce a very appreciable amount of error.

In the annexed form column 1 contains the times, initial and terminal, of each sun and shade observation.

1. Date and times of observation. Feldhausen, 1837. Oct. 30. Initial.	1. Terminal.	2. Exposure, sun (⊙) or shade ×.	3. Readings of the Instrument. A. Initial.	3. B. Terminal.	4. Change per minute. B−A.	5. Radiation in parts of scale.	6. REMARKS.
h m s	m s						
2 15 0	16 0	⊙	+12·0	+43·3	+31·3	....	The times are reduced to *apparent* time, or to the sun's hour angle from the meridian.
16 30	17 30	×	45·2	42·8	− 2·4	34·75	
18 0	19 0	⊙	14·8	48·2	+33·4	35·40	Zero withdrawn.
19 30	20 30	×	28·0	26·8	− 1·4	34·85	
21 0	22 0	⊙	9·4	43·9	+33·5	34·75	
22 30	23 30	×	46·6	45·5	− 1·1	34·95	
24 0	25 0	⊙	9·0	43·2	+34·2	....	General mean per formula = 34·73 for $2_h\ 20_m\ 0_s$ of apparent time.

tion. Column 2 expresses by an appropriate mark, ⊙ and ×, the exposure, whether in sun or shade. Column 3 contains the readings, initial and terminal, (A and B). Column 4 gives the values of B − A, with its algebraical sign expressing the rise and fall per minute. And here it may be observed, that if by

forgetfulness the exact minute be passed, the reading off may be made at the next 10^s, and in that case the entry in column 4 must be not the *whole* amount of B − A, but only $\frac{6}{7}$ths of that amount, so as to reduce it to an interval of 60^s precise. Column 5 contains the radiations as derived from successive triplets, $\odot \times \odot$, $\odot \times \odot$, $\odot \times \odot$, &c., by the formula presently to be stated; and in column 6 are entered remarks, such as the state of the sky, wind, &c.; as also (when taken) the sun's altitude, barometer, thermometer, and other readings, &c.

The formula of reduction is as follows. Let $\odot$, $\times$, $\odot'$, $\times'$, $\odot''$, $\times''$, &c. represent the numbers in column 4, with their signs in order, as they stand, or the values of B − A. Then will the numbers in column 5 be respectively,

$$\frac{\odot + \odot'}{2} - \times$$

$$\frac{\times + \times'}{2} + \odot'$$

$$+\frac{\odot' + \odot''}{2} - \times'$$

$$\frac{\times' + \times''}{2} + \odot'',$$

and so on, the algebraic signs being carefully attended to. Thus

$$34{\cdot}75 = +\frac{31{\cdot}3 + 33{\cdot}4}{2} + 2{\cdot}4$$

$$35{\cdot}30 = +\frac{2{\cdot}4 + 1{\cdot}4}{2} + 33{\cdot}4, \text{ \&c.}$$

The mean of a series not exceeding three or four triplets may be had by the formula

$$\frac{\odot + \odot' + \odot'' + \text{\&c.}}{n} - \frac{\times + \times' + \text{\&c.}}{n-1},$$

where n is the number of sun observations, the time corresponding being the middle of the middle shade observation.

A complete actinometer observation cannot consist of less than three sun and two shade observations intermediate; but the more there are taken the better, and in a very clear sunny day it is highly desirable to continue the alternate observations for a long time, even from sunrise to sunset, so as to deduce by a graphical projection the law of diurnal increase and diminution of the solar radiation, which will thus readily become apparent, provided the perfect clearness of the sky continue,—an indispensable condition in these observations, the slightest cloud or haze over the sun being at once marked by a diminution of resulting radiation.

To detect such haze or cirrus, a brown glass applied before the eye is useful, and by the help of such a glass it may here be noticed that solar halos are very frequently to be seen when the glare of light is such as to allow nothing of the sort to be perceived by the unguarded eye.

It is, as observed, essential that the instrument be exposed a few minutes to the sun, to raise its temperature in some slight degree. If this be not done, owing to some cause not very obvious, the first triplet of observations (sun, shade, sun) will give a radiation perceptibly in defect of the truth, as will become distinctly apparent on continuing the series. But it may be as well for a beginner to commence at once reading as soon as the instrument is exposed, and reject

the first two triplets, by which he will see whether he has all his apparatus conveniently arranged, and get settled at his post.

When a series is long continued in a good sun, the instrument grows very hot, and the rise of the liquid in the sun observation decreases, while the fall in the shade increases; nay, towards sunset it will fall even in the sun. This phenomenon (which is at first startling, and seeming to impeach the fidelity of the instrument) is, in fact, perfectly in order, and produces absolutely no irregularity in the resulting march of the radiation. Only it is necessary in casting up the result (in col. 5) to attend carefully to the algebraic signs of the differences in column 4, as in the following example (which, as well as that above given, is one of actual occurrence).

1. Date and times of observation. Wynberg, Nov. 24, 1837.		2 Exposure, sun or shade.	3. Readings of the Instrument.		4. Change per minute. B–A.	5 Radiation in parts of scale.	6. Remarks.
Initial.	Terminal.		A. Initial.	B. Terminal.			
h m s	m s						
6 5 15	... ...	..	... ...	... ...	... ...	... ...	Alt. of ☉ = 7° 19′
9 0	10 0	☉	+ 9·0	+ 9·7	+ 0·7		
10 30	11 30	×	23·0	10·8	– 12·2	11·25	
12 0	13 0	☉	34·0	31·4	– 2·6	9·25	
13 30	14 30	×	28·5	17·0	– 11·5	8·20	Cirrus, haze coming on.
15 0	16 0	☉	12·0	8·0	– 4·0		
6 19 15	... ...	...	... ...	... ...	... ...	... ...	Alt. of ☉ = 4° 37′

Every series of actinometer observations should be accompanied with notices in the column of remarks of the state of the wind and sky generally, the approach

of any cloud (as seen in the coloured glass) near to the sun; the barometer and thermometers, *dry* and *wet*, should especially be read off more than once during the series, if a long one, and, if kept up during several hours, hourly. The times should be correct to the nearest minute, at least as serving to calculate the sun's altitude; but if this be taken (to the nearest minute or two) with a pocket sextant, or even by a style and shadow, frequently (at intervals of an hour or less), when the sun is rising or setting, it will add much to the immediate interest of the observations. When the sun is near the horizon, its reflection from the sea, or any neighbouring water, must be prevented from striking on the instrument; and similarly of snow in cold regions, or on great elevations in alpine countries.

Every actinometer should be provided with a spare glass, and all the glasses should be marked with a diamond; and it should always be noted at the head of the column of remarks, which glass is used, as the co-efficient of reduction from the parts of the scale (which are arbitrary) to parts of the *unit of radiation* varies with the glass used.

In the case of the actinometers sent out with the Expedition and to the fixed observatories, it was not practicable to ascertain these co-efficients for each instrument and each glass, owing to the total absence of any favourable opportunity of sunshine. The values of the parts of the respective scales of the instruments, as determined approximatively by careful measurement of the dimensions, were as follows:—

Marks of the Actinometer.		Multiplier for reducing parts observed to parts of a standard retained in possession, marked A 1.	Approximate value of one part of scale in Actines.
Maker's Mark.	Private Mark.		
1	K	1·4909	7·085
2	L	1·3726	6·523
3	M	1·4020	6·663
A 4	N	1·6550	7·864
A 5	O	1·4403	6·844
6	P	1·0608	5·041

The dimensions of the instruments which are used in these reductions are,

1st. The external diameter of the cylinder containing the coloured liquid, *i. e.*, its mean diameter, if on measurement with fine callipers its two ends be found to differ.

2nd. The length of that portion of it which receives the sunbeam.

The product of these two data gives the area of the section of the sunbeam effective in raising the temperature, and which, though not all *equally* effective, by reason of the cylindrical form of the glass, is yet effective in *the same ratio* in all of them by reason of their general similarity of figure.

3rd. The content (in water grains) of 100 parts in length of the capillary tube used for the scale. This may best be determined by gauging it with mercury before it is soldered to the cylinder, and ought always to be so determined by the maker; but when fitted, this is impracticable, and the measurement of the element in question must be performed as follows:—

The instrument being placed horizontally, and allowed to attain the precise temperature of the apartment, let the liquid be brought to zero by the motion of the screw; after which let the screw be turned precisely one revolution, or half revolution (as the scale may require) *in*, and note the rise of the liquid in parts of the scale. This must be done several times, alternately screwing *in* and *out*. The screw must then be taken out; its threads counted, and the weight of water displaced from a narrow vessel exactly full, by the immersion of the whole length occupied by the thread, exactly ascertained by a nice balance; after which a very simple calculation will give the value of the parts of the scale in water grains required; this process was followed in the case of the instruments above mentioned, and if carefully conducted is susceptible of great precision.

The glasses as well as the cylinders and capillary stems of the instruments, if accidentally broken, should have their fragments carefully preserved and labelled.

The unit of solar radiation to be adopted in the ultimate reduction of the actinometric observations is the *actine*, by which is understood that intensity of solar radiation, which at a vertical incidence, and supposing it wholly absorbed, would suffice to melt one millionth part of a metre in thickness, from the surface of a sheet of ice horizontally exposed to its action per minute of mean solar time; but it will be well to reserve the reduction of the radiations as expressed in parts of the scale to their values in terms of their unit until the final discussion of the observations.

Meanwhile, no opportunities should be lost of *comparing* together the indications of different actinometers under similar and favourable circumstances, so as to establish a correspondence of scales, which in case of accident happening to one of the instruments, will preserve its registered observations from loss.

The comparison of two actinometers may be executed by one observer using alternately each of the two instruments, thus,—

Instrument A.	Instrument B.	A.	Etc.
⊙ .... × .... ⊙	⊙ .... × .... ⊙	⊙ .... × .... ⊙	

beginning and ending with the same; though it would be more conveniently done by two observers observing simultaneously at the same place, and each registering his own instrument. An hour or two thus devoted to comparisons in a calm clear day, and under easy circumstances, will in all cases be extremely well bestowed.

Neither should each observer neglect to determine for himself the heat stopped by each of his glasses. This may be done also by alternating triplets of observation made with the glass on and off, thus,—

Glass off.	Glass on.	Glass off.	Etc.
⊙ .... × .... ⊙	⊙ .... × .... ⊙	⊙ .... × .... ⊙	

beginning and ending with the glass off, and (as in all cases) beginning and ending each *triplet* with the sun observation. For the purpose now in question a very *calm* day must be chosen, and a great many triplets must be taken in succession. It will be found that a single thickness of the ordinary bluish or greenish plate glass stops about 0·20 (= ⅕) of the incident calorific rays; a second glass about 0·16 (or a materially less proportion) of those which have escaped the action of the first. No two glasses, however, are precisely alike in this respect.

Very interesting observations may be made by two observers furnished with well-prepared actinometers, the one stationed at the summit, the other at the foot of some great elevation, especially if the stations can be so selected that the observers shall be nearly in the line of the incident sunbeam at the time of observation, so as both to lie in the atmospheric column traversed by the rays. Many convenient stations of this kind might be found in mountainous countries; and by repeating the observation two or three times under favourable circumstances, interchanging observers and instruments, &c., and accompanying the observations with all circumstantial and local elements of precision, there is no doubt that the co-efficient of extinction of solar heat in traversing at least the lower strata of our atmosphere might be obtained with much exactness, and thus a highly valuable datum secured to science. The observers would, of course, agree to make their observations strictly simultaneous, and should, therefore, compare watches before parting.

The actinometer is also well calculated for measuring the defalcation of heat during any considerable eclipse of the sun; and this is pointed out as an object worthy of attention, inasmuch as many eclipses invisible or insignificant in one locality, are great or even total in others. The observations should commence an hour at least before the eclipse begins, and be continued an hour beyond its termination, and the series should be uninterrupted, leaving to others to watch the phases of the eclipse. The atmospheric circumstances should be most carefully noted during the whole series.

Though out of the question in the circumstances immediately under contemplation, it may not be amiss to remind aëronauts, that observations of the actinometer may, no doubt, be made with considerable ease and precision in the car of a balloon, and if accompanied with good barometric and hygrometric simultaneous observations aloft and below, as well as with a careful and copious registry of the temperatures of the air corresponding to each successive step of depression in the barometric column, would in every point of view be most valuable, especially as respects the intricate problem of astronomical refractions.

In the year 1832 Professor Forbes, being in Switzerland, embraced the opportunity of using the actinometer, according to the suggestion and instructions of Sir John Herschel, to find the loss of solar radiation by simultaneous observations at the top and bottom of a mountain. He was assisted in his operations by

Professor Kämtz, of Halle, who was stationed on the top of the Faulhorn, an insulated mountain which lies exactly between the valley of Grindelwald and the lake of Brientz, 8747 feet above the level of the sea, and 6844 above the lake, from the level of which Professor Forbes made his observations. The difference of the barometers at the two stations was found to be a little above seven inches, or nearly one-fourth of the whole weight of the atmosphere. Numerous observations were made on different days, when the sky from the lower station appeared to be in a perfectly transparent and unexceptionable condition; but it was only on the 25th September that a series of comparative results was obtained which was worthy of entire confidence; the others affording "no other immediate result than that of showing how unavailing such observations are unless made under the most favourable circumstances with regard to weather."

At every hour from morning to sunset the state of the atmosphere was ascertained by the barometer, thermometer, and wet-bulb hygrometer, at both stations; thus giving as accurate a knowledge as the circumstances permitted of the state of the interrupted column.

The results finally reduced and corrected are contained in the following Table* (E.), and have been projected in the accompanying curves (XII. and XIII., pl. 21.)

* *Phil. Trans.*, 1842, part ii. p. 250.

Table XXXVI. September 25, 1832.

Apparent Time.	Brientz.					Faulhorn.					Difference dry and moist thermometers.		Mean Temperature, F.	Difference of Pressure.	[c] Mean Dampness.	Loss of Solar Intensity.	Ratio of Actinometers $\frac{b}{a}$.	Ratio of loss to effect at upper station *.	Sun's apparent altitude.	Barometer × sec. Z.D.		[d] Difference.	c × d
	Barom. at 0° C. in millimetres.	Temperature, Fahrenheit.	Moist Thermometer, F.	Ratio to Saturation.	[a] Actinometer, B. 2.	Barometer at 0° C.	Temperature, Fahrenheit.	Moist Thermometer, F.	Ratio to Saturation.	[b] Actinometer, B. 2.	Brientz.	Faulhorn.								Brientz.	Faulhorn.		
	m.m.	°	°			m.m.	°	°			°	°		m.m.					° ′	m.m.	m.m.		
7½	725·06	52·8?	49·0	·779		557·49	39·1	24·9	·141	18·2?	3·8	14·2	45·9	167·57	·460				14 42	2857·0	2197·0	660·0	303·6
8	725·06	54·5	51·1	·807		557·53	40·0	26·5	·193	22·2	3·4	13·5	47·2	167·53	·500				19 26	2179·0	1675·8	503·2	251·6
8½	725·06	55·3	52·[illegible]	·819	22·8	557·53	40·4	27·1	·205	24·5	3·2	13·3	47·8	167·53	·512	1·7°	1·075	·0694	21 48	1952·2	1501·4	450·8	230·8
9	725·06	57·5	54·3	·825	25·5	557·69	40·7	27·9	·236	29·1	3·2	12·8	49·1	167·37	·530	3·6	1·141	·1237	28 18	1529·2	1176·4	352·8	187·0
10	725·03	60·1	55·4	·756	27·6	557·89	41·0	27·8	·223	33·5	4·7	13·2	50·5	167·14	·489	5·9	1·214	·1761	35 39	1244·1	957·3	286·8	140·2
11	724·57	61·5	56·3	·736	28·7	557·96	41·3	28·2	·232	38·6	5·2	13·1	51·4	166·61	·484	9·9	1·345	·2565	40 38	1112·6	856·8	255·8	123·8
12	723·68	65·2	57·3	·631	30·6	557·87	41·9	29·4	·273	37·3	7·9	12·5	53·5	165·81	·452	6·7	1·219	·1796	42 24	1073·2	827·4	245·8	111·1
1	723·42	67·7	58·6	·593	31·8	557·64	43·7	31·5	·310	34·3	9·1	12·2	55·7	165·78	·451	2·5	1·078	·0729	40 37	1111·2	856·7	254·5	114·8
2	723·30	68·5	59·5	·603	27·6	557·55	45·7	35·8	·450	33·3	9·0	9·9	57·1	165·75	·526	5·7	1·207	·1712	35 36	1242·5	957·9	284·6	149·7
3	723·16	65·6	59·5	·713	24·2	557·37	45·9	37·3	·522	29·5	6·1	8·6	55·7	165·79	·617	5·3	1·219	·1796	28 14	1528·7	1178·3	350·4	216·2
4	722·95	64·1	57·8	·696	19·9	557·09	43·5	35·7	·544	24·0	6·3	7·8	53·8	165·86	·620	4·1	1·206	·1708	19 20	2183·7	1683·1	500·6	310·4
4½	722·85	63·1	58·2	·759	16·2	556·91	41·7	35·4	·611	21·4	4·9	6·3	52·4	165·94	·685	5·3	1·321	·2477	14 34	2874·0	2214·5	659·5	451·7
5	722·75?	61·2?	59·5	·910	10·0?	556·73	39·7	35·2	·709	12·0?	1·7	4·5	50·4	166·02	·809	2·0?	1·200?	·1667?	9 34	4348·8 *	3350·2	998·6	807·9

* Projected in Curve XIX.

*Upon these results Professor Forbes makes the following observations**:—1. That the intensity at the higher station always exceeded that at the lower by a very appreciable quantity, varying from nearly ten to nearly two degrees of the actinometer, B 2.

2. That this loss, compared to the intensity at the higher station, varied from $\frac{7}{100}$, or $\frac{1}{14}$th of the total amount, to above $\frac{25}{100}$, or $\frac{1}{4}$th of the total amount.

3. That this loss appears to have varied rather irregularly, having two maxima nearly equal at 11 A.M. and $4\frac{1}{2}$ P.M.

Viewed generally, it may be observed in the curves,—*first*, that they differ from the diurnal temperature curves by drooping more rapidly at each extremity; *secondly*, that both curves have a morning and afternoon inflation before and after they attain their maximum; *thirdly*, that the curve of intensities at the upper station lies wholly above the curve for the lower station; *fourthly*, that the range of the former curve is greater than that of the latter; *fifthly*, is sooner attained in the former than the latter. Professor Forbes is quite confident that these *five* peculiarities will be found to be reproduced from the projection of every series made under equally favourable circumstances.

He ascribes the rapid fall of the actinometric curves to the extreme rapidity with which the length of path through the atmosphere increases as the sun approaches the horizon; the disappearance of the sun

* *Phil. Trans.*, 1842, part ii. p. 251.

corresponding to an instant extinction of the force of radiation. With respect to the points of contrary flexure, they probably arise from a twofold effect of the sun's radiation. The one is, the increased intensity as the sun is higher; the other is, the transference of vapour from the lower to the higher regions of the air by the heating of the lower strata, producing incipient condensation at a certain elevation, and slight clouds which often appear between ten and twelve o'clock. As the sun's power diminishes, and the vapours redescend into the less rarefied and warmer regions, they are in some degree redissolved in the afternoon, and the increased transparency of the atmosphere checks the downward progress of the curve due to the increasing obliquity of the rays. The curve at the upper station lies wholly above that at the lower, on account of the absorption of heat in every case by the intercepted air; and it of course follows that the range at the higher station must be greater than at the lower, as both pass through zero. Lastly, the maximum of intensity is sooner attained above than below, because the sun shines with a disproportionate intensity during the morning on the upper station, owing to the mass of vapours being then in the valleys.

Upon the whole, from a comparison of these two curves of solar intensity, Professor Forbes deduces the mean loss of heat between the two stations, and concludes, on the hypothesis of uniform opacity, that about one-third of the solar heat is lost by vertical transmission through the atmosphere.

There can be little doubt that the physical cause of this absorption is the specific difference between

the rays of heat, which by parting with their more absorbable elements become continually more persistent in their character. Professor Forbes is of opinion, from the discussion of his observations in different ways, that the residual heat is more and more freely transmitted through similar successive strata of the atmosphere. The law, however, of the *extinction* of the solar rays in passing through the atmosphere, though a highly interesting object of research, is by no means the only or the most important question to be resolved. What becomes of the heat thus absorbed? Is it radiated in rays of a different order from the body of the air? from the clouds? or is it rendered latent by the conversion of the latter into vapour? Can radiant heat be ever, properly, said to be extinguished like light? It may change its mode of action, but must it not always remain in some mode or other active?

Other modes of observation, and probably other instruments will be required, before these and many similar important questions can be answered. Comparative observations with actinometers constructed with different absorbent liquids and different surfaces would doubtless be instructive; and looking to the results just recorded of comparative experiments with thermometers clothed with black and white wool and placed in reflectors, specific differences in the rays of heat which fill the atmosphere whilst the sun is above the horizon might thus be detected, if not accurately measured. The subject is at present so little advanced that the roughest observations should not be wholly despised.

ON

THE WATER BAROMETER

ERECTED IN THE HALL OF THE ROYAL SOCIETY.

ON

THE WATER-BAROMETER ERECTED IN THE HALL OF THE ROYAL SOCIETY;

BEING A PAPER READ BEFORE THE ROYAL SOCIETY, JUNE 21, 1832, AND REPRINTED BY PERMISSION FROM THE *Philosophical Transactions* FOR THE SAME YEAR.

I HAVE for some time entertained an opinion, in common with some others who have turned their attention to the subject, that a good series of observations with a water-barometer, accurately constructed, might throw some light upon several important points of physical science; amongst others, upon the tides of the atmosphere; the horary oscillations of the counterpoising column; the ascending and descending rate of its greater oscillations; and the tension of vapour at different atmospheric temperatures. I have sought in vain in various scientific works, and in the Transactions of Philosophical Societies, for the record of any such observations, or for a description of an instrument calculated to afford the required information with anything approaching to precision. In the first volume of the *History of the French Academy of Sciences*, a cursory reference is made, in the following words, to some experiments of M. Mariotte upon the subject, of which no particulars appear to have been preserved. "Le même M. Mariotte fit aussi à l'observatoire des experiences sur le baromètre ordinaire à

mercure comparé au baromètre à eau. Dans l'un le mercure s'elèva à 28 pouces, et dans l'autre l'eau fut à 31 pieds $\frac{1}{3}$. Cequi donne le rapport du mercure à l'eau de 13½ à 1*."

It also appears that Otto Guericke constructed a philosophical toy† for the amusement of himself and friends, upon the principle of the water-barometer; but the column of water probably in this, as in all the other instances which I have met with, was raised by the imperfect rarefaction of the air in the tube above it, or by filling with water a metallic tube, of sufficient length, cemented to a glass one at its upper extremity, and fitted with a stop-cock at each end; so that when full the upper one might be closed and the lower opened, when the water would fall till it afforded an equipoise to the pressure of the atmosphere. The imperfections of such an instrument, it is quite clear, would render it totally unfit for the delicate investigations required in the present state of science; as, to render the observations of any value, it is absolutely necessary that the water should be thoroughly purged of air, by boiling, and its insinuation or re-absorption

* *Hist. de l'Académie*, tom. i. p. 234.

† It consisted of a tube above 30 feet, rising along the wall, and terminated by a tall and rather wide tube hermetically sealed, containing a toy of the shape of a man. The whole being filled with water and set in a bason on the ground, the column of liquid settled to the proper altitude, and left the toy floating on its surface; but all the lower part of the tube being concealed under the wainscoting, the little image made its appearance only in fine weather. To this whimsical contrivance he gave the name of *Anemoscope* or *Semper Vivum*.

effectually guarded against, I was convinced that the only chance of securing these two necessary ends, was to form the whole length of tube of one piece of glass, and to boil the water in it, as is done with mercury in the common barometer. The practical difficulties which opposed themselves to such a construction long appeared to me insurmountable; but I at length contrived a plan for the purpose, which, having been honoured with the approval of the late Meteorological Committee of this Society, was ordered to be carried into execution by the President and Council.

The first object was to procure a glass tube of the proper diameter, and of sufficient length for the purpose. Messrs. Pellatt and Co., of the Falcon glass-house, very obligingly consented, upon application, to permit the trial to be made at their works; such an undertaking never having been before attempted. Accordingly, a very strong packing-case was prepared of one-inch and a-half deal, forty feet long, five inches wide, and four inches deep, inside measure; with a cover of the same thickness to screw down upon it. This was carried to the glass-house, and being laid in the yard with its cover off, small pieces of wood were placed across its bottom, at about one-foot intervals. The only instructions given to the workman were to make a tube of the length of the box, which should not be less than half an inch internal diameter, and as equal throughout its length as possible; and the manual dexterity with which he proceeded to effect this was well worthy of admiration. Having collected the glass at the end of his tube, and blown the cavity,

a boy attached another iron with a small lump of hot glass to the opposite extremity of the mass, and drew the tube out by walking away to the required distance. The curve of the hot glass was so great that the workmen could scarcely prevent it from touching the pavement, (which of course would have caused its instant destruction,) by holding its extremities above their heads. While it was still red-hot and pliant, it was carefully laid upon the transverse pieces in the box, and rolled backwards and forwards till cool; by which a perfectly cylindrical form was secured. While the drawing process was going on, others of the workmen fanned with their hats, for the purpose of cooling, the parts which appeared to be extending too fast; and by such simple means a tube was perfected without a flaw, and of the greatest regularity; varying only from one inch diameter at its lower extremity to 0·8 inch at its upper.

The facility with which this process was conducted was so much greater than had been anticipated, that I immediately determined to have another tube made; that in case of any accident happening to the first, during the after operations, all the preliminary labour might not be thrown away. This was accordingly effected by rolling it upon the steps of a ladder placed horizontally upon the ground for that purpose. After it was cool it was lifted into the box by six men standing at equal intervals apart, and carefully placed by the side of the first. The box was then packed with hay, the cover screwed down, and carried upon men's shoulders to a convenient place for the further operations.

As it was not intended that the tubes should ever be removed from the case in which they had been originally deposited, the first step was to prepare the means of fixing them in their proper places when raised to the perpendicular position. For this purpose pieces of wood were provided of half the depth of the box, upon the upper edge of each of which a semicircle was hollowed out of the exact dimensions of half the cylinder of the tube. These were placed under the tube at equal intervals; and other similar pieces prepared for screwing down upon the upper side of the tube; in such a way that the two semicircles meeting, formed collars, which tightly embraced it, and fixed it in the centre of the box. The corners of the lower pieces were also cut away so as to inclose the square tube (*e*, *f*), Plate XIX., which was placed in one of the angles of the case, and thus tightly fixed. The next object was to prepare the tube (*a*, *b*) itself for its final fixture; and for this purpose, as it was longer than necessary, three feet were cut off from its upper extremity with a file; a small thermometer (*c*, *d*) which had been made for the purpose, with a platinum scale carrying a spring of the same metal upon its back, was pushed down into the tube to a situation where it had been calculated it would always be immersed in the water, notwithstanding its oscillations; and where a slight tapering of the tube insured its being fixed by the action of the spring. By a careful application of the blow-pipe the glass was now softened, and an external collar (*g*) pushed up upon it, about eight inches from its upper extremity. This was deemed necessary

to give it additional support, and to prevent its slipping in its proper position. The upper extremity was then contracted and drawn out into a small tube of about six inches long, and of about one quarter of an inch diameter. These preparations having been successfully completed, a small stop-cock was fitted to the upper end of the contracted tube by very careful grinding, and secured in its place by a little white lead. The tubes were then again packed in their case, and the cover screwed down.

A small copper steam-boiler (*h*, *i*) was now constructed of what is called the waggon shape, and which was intended to form the cistern of the barometer. Without the cylindrical cover (*k*, *l*) it is eighteen inches long, eleven inches wide, and ten inches deep. Its bottom is slightly arched; and towards one extremity on the inside is fixed a small cylinder (*m*, *n*) six inches high, and three inches diameter; the object of which is to form a receptacle into which, the lower end of the tube being made to dip, the great body of the water might be at any time drawn out of the cistern, if required, without, for a short time, disturbing the water in the tube, or allowing any air to ascend into the vacuum. A small hole (*o*) was afterwards drilled in this cylinder, which is six inches from the crown of the arch, and four inches and a half from the bottom; so that the water might be more completely withdrawn. At the other extremity is a cock (*p*) for drawing it off, if at any time it should be necessary to change it. The cover (*k*, *l*) is an arch of the height of six inches. Immediately over the cylinder above described, a

length of five inches (k, q) is fixed and fitted with a stuffing-box for the glass tube to pass through. Beyond this it is made to take off, but may be fixed down by means of screws: on the summit of this moveable end a cock (s) is placed. The whole of the interior has been strongly tinned.

Everything being now prepared, the steam-boiler was set with brickwork in a proper position over a small fire-place, with a temporary flue (t, u) at the foot of the well-staircase conducting to the apartments of the Society. With considerable difficulty and contrivance, the case with the glass tubes was introduced, by permission of the Antiquarian Society, through their library, and fixed against the stairs in a perpendicular direction, immediately over the stuffing-box; and the front of the box being removed, the tube was unpacked and suspended from above over the aperture. It was then very carefully lowered into its proper position in the boiler, and the wooden stays being screwed into their places, it was firmly adjusted. The stuffing-box (m, n), through which it passed into the boiler, was then packed with tow, and intended to be perfectly steam-tight. Part of the upper end of the deal-case was removed with a saw, so as to leave about six feet of the glass tubes exposed.

The object of the whole arrangement was as follows: first to boil the water in the cistern thoroughly, suffering the steam to escape by the cock (s), and then, by closing the latter, to raise the water in the tube, by the elastic force of the vapour acting upon its surface, till it issued in a jet from the small stop-cock

upon its summit. When a sufficient current had thus been forced up, to secure the thorough wetting of the tube, and the total extrication of all particles of air, it was intended to close the stop-cock at the top while the water was still flowing, and at the same moment to relieve the pressure below by opening the cock upon the boiler, and again suffering the steam to escape. It was conceived that when the whole apparatus was cool, the column of water would subside, till it afforded a balance to the pressure of the atmosphere; when the small tube might be sealed by a dexterous application of the blow-pipe, and the stop-cock removed.

Everything being ready for the experiment, a preliminary trial was made of the apparatus on the 10th of June. The boiler was carefully washed with boiling distilled water, and the cover being screwed down, it was filled with distilled water to within five inches and a half of the top. The fire was then lighted in the grate, and in about two hours and a half a powerful current of pure steam issued from the cock (*s*). When this had continued for about half an hour, the cock was gradually closed, and the water rose very slowly in the tube. During its rise it oscillated backwards and forwards two or three inches, but the column was perfectly unbroken and clear. On this occasion it was found impossible to raise it higher than thirteen feet, owing to the stuffing-box and cover not being sufficiently close. The cock upon the boiler was therefore gradually opened, and the column of water slowly subsided, the steam rushing out with consider-

able violence. Several practical points were determined by this experiment, which it was of importance to be acquainted with. The apparatus was found perfectly manageable; the pressure could be regulated with great precision by the cock, and the elasticity of the steam increased by very slow degrees, even when quite shut off. The temperature of the rising column was very moderate, and felt but just warm to the hand at the upper part.

Several little alterations were made in the fireplace, and the part (*v*, *w*) which was immediately under the tube was bricked up, so that the flame was cut off from the front of the boiler; that the steam might be raised from the back part only, and the possibility of any bubble passing up into the tube precluded. The stuffing-box was repacked, and the top screwed down with greater care. The water was drawn off, and fresh distilled water poured in.

It was now determined to prove the apparatus, by raising the column of water by condensed air; and for this purpose the pump of a soda-water machine was connected, by means of a flexible pipe and screw, with a collar (*x*) fixed for the purpose upon the arch of the boiler. As the condensation proceeded, the column of water rose steadily, till it issued with considerable force from the aperture of a small glass tube fixed into the stop-cock on the summit, and bent to an angle to prevent the waste water trickling down the apparatus. When the force of the jet began to decrease, the stopcock was closed, and the cock on the boiler at the same moment opened. After a short interval the

column of water began slowly to decline, and appeared to boil violently from the extrication of air from its surface. The effervescence continued for more than an hour, with decreasing force; and the formation of air-bubbles could be perceived nearly half way down the column. After eighteen hours, the water stood in the tube at about thirty feet eight inches from the level of the water in the cistern.

Advantage was taken of this opportunity to ascertain the relative capacities of the tube and cistern; and it was found, by careful measurement, that the fall of this quantity in the tube occasioned a rise in the level of that in the cistern of one inch and a half, affording a correction of very nearly 0·04 inch for ten inches. Everything having been thus prepared for the final experiment, a fire was lighted under the boiler at 11 A.M. of the 13th of June, and at half-past 1 pure steam issued with force from the cock (*s*) on the top of the boiler. When this was closed, the water began to rise slowly and steadily in the tube, oscillating at times about one inch and a half. More than an hour elapsed before the column of liquid reached the thermometer (*c*, *d*) at the upper end, when its temperature was found to vary from 85° to 90°. It still continued to rise very gently, till it issued with some force in an unbroken jet from the small tube which had been adjusted to the stop-cock. Three pints of water were thus drawn off, and the thermometer rose to 110°. The stop-cock on the top of the tube was then closed, and the cock on the top of the boiler simultaneously opened. The steam rushed forth

from the latter with great violence, and after a considerable interval the column began very gently to fall from the top, without any boiling, or the slightest indication of air-bubbles. When it appeared to be stationary, the sealing was attempted; the small part of the tube, to which the stop-cock was attached, was successfully drawn off and closed without the slightest disturbance of the column of water; but in cooling it unfortunately cracked. The fissure thus occasioned was very minute, but rendered the resumption of the whole process necessary. The most difficult part of this to effect, was the drawing off and contraction of the tube to fit it again for sealing. It was determined, upon consideration, not to replace the stop-cock, but to rely upon the pressure of the operator's thumb to cut off the communication with the external air during the sealing.

As it was necessary to the operation that the tube should be turned upon its axis, it was unpacked from the stuffing-box of the boiler, and loosened from its different supports; and everything was again successfully adjusted with great dexterity by Mr. Newman, who overcame the difficulties of these various processes with the greatest skill. It would be tedious to repeat the further steps of the progress; the boiling was conducted precisely in the manner which I have just described, and the tube was finally and permanently closed on the 18th of June. Not the slightest speck or air-bubble has from that moment been detected in the column of water.

While the water in the boiler, which now consti-

tutes the cistern of the barometer, was still warm, a quantity of the purest castor oil (Oleum Ricini) was poured into it till the surface was covered to the depth of half an inch; this was done for the purpose of cutting off the communication of the atmosphere with the water, and with the view of preventing the absorption of the air. Some of the same oil was poured upon the surface of some distilled water in a wide-mouthed glass vessel, and being lightly covered with paper was set by in a closet, that any change might be detected to which it might be liable under such circumstances.

The adjustment of a scale was the next object of importance. For this purpose a hollow brass rod (1, 2) was prepared of $\frac{3}{8}$ths of an inch in diameter, and adjusted by means of a screw at the upper end to a flat ruler of brass (2, 3) divided into inches, and carrying a vernier (4) by which the hundredth part of an inch is easily read off, and which is moveable from the outside of the case of the instrument by means of a rack and screw (5). The same rack and screw also moves a brass screen (6, 7), which rises and falls with the vernier and protects the tube from the heating influence of the breath or hand; a small thermometer is inserted into this screen. The rod was measured from a scale formerly belonging to the late Mr. Cavendish, and now the property of Mr. Newman, by marking it with a beam compass at intervals of two feet, and afterwards repeating the process at intervals of sixteen inches. The two measures corresponded to the one twentieth of an inch; the difference being found to depend upon the multiplication of a small

error in laying down the sixteen inches, and corrected accordingly.

The rod was next placed in the case of the barometer by the side of the tube, being made to pass through the wooden stays of the tube, in which it can freely move. At its lower end an ivory point of known length was fixed by which it was very carefully brought into exact contact with the surface of the oil in the cistern; the flat scale was then carefully adjusted to its upper end, and it was fixed at the lower end by screws to the top of the copper cistern. The column of water was thus found to stand exactly thirty-three feet four inches, or four hundred inches, above the level of the fluid in the cistern. This, then, is the neutral point of the instrument, above or below which a correction of $\pm \cdot 02$ inch must be made for every ascent or descent of five inches in the tube. The whole instrument has been inclosed in an exterior ornamental case resembling an architectural column. The pedestal (A, B) conceals the boiler with its brick-work, and upon the capital (C, D) stands a glass-case including that part of the tube to which the oscillations are confined, and the apparatus for measuring them.

As much interest will attach to the accurate comparison of the water-barometer with the mercurial barometer, it is of great importance that several corrections should be attended to in the first reading of their respective heights, to reduce the columns to the same invariable circumstances under which alone such comparison can be properly made; for this purpose the

variations of the density of the liquids, and the expansion of the scales, from variations of temperature, together with the capillary action of the tubes, must be taken into account. To facilitate this object, I have constructed the two following Tables of double entry; by which the observations may be reduced to the temperature of 40° (39°·38) or that of the maximum density of water, in which the expansion of the brass scales is also allowed for; which is a correction of considerable amount in the long scale of the water-barometer.

The data upon which these Tables have been calculated, are as follows:—

1st, The specific gravity of water at different temperatures, as determined by the experiments of Hallström, taken from Dr. Thomson's late work upon Heat and Electricity, p. 28.

2nd, The determination of the linear expansion of brass at ·0000104 per degree of Fahrenheit.

The height of the column is assumed to be in inverse proportion to the specific gravity; and the correction to the maximum density at 40° (or more correctly 39°·38) is calculated accordingly. From this correction is deducted, or to it is added, the expansion or contraction of the brass scale on either side of 60°, calculated on the preceding datum.

Table (XXXVII.) *of Corrections for Temperature for the Water-Barometer. Standard Temperature of Scale* 60°. *Maximum Density of Water* 40°.

Temperature. Exact.	Temperature. Approx.	Inches. 350	Inches. 360	Inches. 370	Inches. 380	Inches. 390	Inches. 400	Inches. 410
35·6°	35°	−·101	−·103	−·106	−·108	−·112	−·115	−·118
39·38	40	−·072	−·074	−·077	−·079	−·081	−·083	−·085
44·6	45	−·073	−·075	−·077	−·079	−·081	−·083	−·085
50	50	−·113	−·115	−·118	−·122	−·124	−·128	−·132
55·4	55	−·191	−·195	−·201	−·206	−·211	−·217	−·223
59	60	−·258	−·264	−·272	−·279	−·286	−·294	−·302
64·4	65	−·398	−·409	−·420	−·431	−·443	−·454	−·466
69·5	70	−·575	−·590	−·606	−·623	−·639	−·656	−·673
75·2	75	−·786	−·808	−·831	−·853	−·876	−·898	−·921

With regard to the capillary action of the tube, which of course is in the opposite direction to that of the mercurial barometer, Dr. Young has calculated* that the central elevation for water in a tube of which the diameter is ·49964 inch (which is almost exactly the diameter of the tube within the range of the oscillations,) is ·035, and the marginal elevation ·172.

In my first use of the instrument, I conceived that the observation was made with most certainty by bringing the vernier to coincide with the marginal elevation of the water; and in the following observations the correction of −·17 has been applied accordingly. Mr. Hudson has since shown me, that by reflecting the light upon the column from behind, the observation from the centre is made with the greatest precision; and in some observations which have been

* Young's *Lectures on Natural Philosophy*, vol. ii. p. 669.

kindly furnished by that gentleman, the correction of −·03 only has been applied. The difference of the two corrections deduced from the calculation of Dr. Young as above, agrees very nearly with the difference of the two readings upon the barometer when carefully observed.

As the usual Tables for the thermometric correction of the mercurial barometer are calculated for 32°, I considered it necessary to calculate a fresh Table for the temperature of 40°; that both the water and the mercury might be reduced to the same standard temperature. The dilatation in volume of mercury per degree of Fahrenheit has been taken, on the authority of MM. Dulong and Petit, at ·0001001 of the volume at 32°. And the height of the column has been assumed to be in the ratio of the volume at 40° to the volume at the observed temperature. To the correction thus obtained has been added, or from it has been deducted, the expansion or contraction of the brass scale on either side of the standard temperature 60°.

TABLE (XXXVIII.) *of Corrections for Temperature for the Mercurial Barometer. Standard Temperature of Scale* 60°. *Volume of Mercury at* 40° *Standard.*

Temperature.	Inches. 28·	Inches. 28·5	Inches. 29·	Inches. 29·5	Inches. 30·	Inches. 30·5
° 35	+·007	+·008	+·008	+·008	+·008	+·008
40	−·005	−·006	−·006	−·006	−·006	−·006
45	−·018	−·018	−·018	−·018	−·019	−·019
50	−·030	−·031	−·032	−·032	−·033	−·033
55	−·043	−·043	−·044	−·045	−·046	−·046
60	−·056	−·057	−·058	−·059	−·060	−·061
65	−·069	−·070	−·071	−·072	−·074	−·075
70	−·081	−·082	−·084	−·085	−·087	−·088
75	−·094	−·096	−·097	−·099	−·101	−·102

The mercurial barometer, with which the following comparison has been made, is of a portable construction, and has been fully described on a former occasion*. It is the first to which a platinum guard was ever applied, and it still remains perfectly free from air. The correction of +·044 for capillary action has been experimentally verified, upon more than one occasion, by comparison with a barometer of half an inch bore, in which no such correction is necessary.

I have not hitherto had it in my power to institute such a series of observations as I think the interest of the subject would have justified; as I have been obliged to depend upon my own exertions, or of those who from pure love of science have been willing to assist me in this laborious drudgery, at such intervals as the pressure of other engagements would permit. Of these by far the most important are the hourly observations of Mr. Hudson, which, with the assistance of some of the members of his family, he had the resolution to persevere in for fifteen days, and which he has communicated to the Society. Prior to these were the following observations made at my request by Mr. Roberton in the months of August and September, 1830, at different hours of the day; but generally at 9 A.M. and 3 P.M. They include a very considerable range of temperature (from 57° to 74°), and serve to test the accuracy of the instruments brought into comparison shortly after the completion of the water-barometer, and that of the different corrections which have been applied to them.

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* Essay on the Prevention of the Deterioration of Barometers, in the present Volume.

The first column of the following Table records the date, and the second the hour of the observations. The third column contains the temperature of the internal thermometer (*c*, *d*), and the fourth that of the external thermometer (6, 7). The fifth shows the corrected height of the water-barometer; the sixth the temperature of the thermometer attached to the mercurial barometer. This, it will be observed, sometimes differs several degrees from the former; and, when this is the case, the mean has been taken as the temperature by which to correct the length of the scale; as standing at the bottom of the column, it most probably indicated the temperature of the lower extremity. The seventh column contains the corrected height of the mercurial barometer. In the eighth column I have placed the height of the column of water reduced to the corresponding height in mercury. As the basis of this calculation, I have taken the specific gravity of mercury at 40°, 13·624, as determined, at my request, by Mr. Faraday at the time when I fitted up the large mercurial barometer belonging to the Society. The ninth column exhibits the differences of the two columns, or the amount of the depression of the column of water by the included vapour, expressed in parts of an inch of mercury.

By the side of these differences I have placed, in the tenth column, the elasticity of aqueous vapour due to the temperature of the surface water in the barometer, calculated from the data of Dr. Ure. The eleventh column exhibits the differences of the two preceding. The mean results of every ten observations are also added to the register.

Register I. *Of the Temperature and Height of the Water and Mercurial Barometers.*

1830.	Hour.	Thermometers.		Water-Barometer.	Temperature of Mercury.	Mercurial Barometer.	Water Barometer reduced to Mercury.	Difference.	Elasticity of Vapour.	Difference.
		In.	Out.							
	A.M.	°	°	Inches.	°	Inches.	Inches.	Inch.	Inch.	Inch.
July 31	3	74·5	74·6	396·605	73·8	29·979	29·110	·869	·877	−·008
Aug. 1	9	67·3	67·7	398·111	67·2	29·927	29·221	·706	·699	+·007
—	10	68·0	68·3	397·728	67·8	29·924	29·192	·732	·722	+·010
—	3	70·5	70·7	396·327	71·7	29·879	29·090	·780	·770	+·010
2	12	66·2	66·6	396·158	65·8	29·772	29·077	·695	·678	+·017
3	9	63·6	63·7	399·243	63·6	29·948	29·304	·649	·615	+·034
4	3	68·7	68·7	397·661	69·3	29·921	29·188	·733	·733	+·000
5	2	69·6	70·2	396·413	69·7	29·869	29·097	·772	·770	+·002
27	1	61·5	61·8	395·025	64·2	29·636	28·994	·642	·594	+·048
28	9	58·2	58·6	391·755	58·2	29·337	28·754	·583	·526	+·057
Means .	..	66·8	67·1	396·503	67·1	29·809	29·103	·706	·699	+·007
Aug. 28	12	58·8	58·2	391·732	59·4	29·350	28·753	·597	·548	+·054
—	3	59·6	60·0	392·294	60·4	29·396	28·794	·602	·560	+·042
29	9	57·8	59·2	398·837	59·0	29·854	29·274	·580	·526	+·054
—	3	59·8	60·5	399·333	60·8	29·913	29·310	·603	·560	+·043
30	9	57·8	58·6	403·059	57·6	30·157	29·584	·573	·526	+·047
—	1	59·4	60·2	402·396	60·8	30·150	29·535	·615	·560	+·055
—	3	60·6	61·2	401·993	60·6	30·135	29·506	·629	·568	+·061
31	9	57·8	58·8	403·959	57·4	30·228	29·650	·578	·526	+·052
—	3	60·6	61·8	402·696	61·0	30·206	29·557	·649	·577	+·072
Sept. 1	9	58·8	59·2	404·417	58·5	30·273				
Means .	..	58·9	59·7	400·071	59·5	29·966	29·364	·602	·543	+·059
Sept. 1	3	62·0	63·0	402·886	63·2	30·244	29·571	·673	·605	+·068
2	9	57·8	58·4	402·742	56·0	30·149	29·560	·589	·526	+·069
—	3	61·0	62·0	400·246	63·0	30·033	29·377	·656	·594	+·062
—	6	61·8	62·0	399·186	63·0	29·974	29·300	·674	·594	+·080
3	9	58·2	58·5	397·739	58·2	29·837	29·192	·645	·526	+·119
—	3	60·0	60·6	396·952	61·4	29·771	29·136	·635	·560	+·075
4	9	58·5	59·4	399·277	58·2	29·890	29·296	·594	·534	+·060
—	3	60·2	60·8	398·895	60·4	29·959	29·278	·681	·560	+·121
5	9	57·5	58·0	396·230	56·2	29·672	29·083	·589	·526	+·068
—	3	60·6	60·8	395·293	61·3	29·656	29·014	·642	·568	+·074
Means .	..	59·7	60·3	398·945	60·0	29·918	29·282	·636	·560	+·074
Sept. 6	9	58·2	58·8	394·135	58·8	29·532	28·916	·616	·534	+·082
—	3	59·2	59·8	392·911	60·0	29·457	28·781	·676	·551	+·125
7	9	58·8	59·2	396·356	59·2	29·682	29·092	·590	·543	+·047
—	3	59·5	59·8	396·614	59·6	29·700	29·111	·589	·551	+·038
8	9	58·1	58·6	400·057	58·2	29·949	29·364	·585	·526	+·059
—	3	60·8	61·3	399·675	60·3	29·962	29·335	·627	·577	+·050
9	9	57·0	57·6	398·328	56·0	29·819	29·236	·583	·508	+·083
—	3	58·2	58·2	397·177	57·8	29·762	29·152	·610	·526	[illegible]084
Means .	..	58·7	59·1	396·906	58·7	29·732	29·132	·600	·543	+·057

The most striking result of this comparison is, the almost exact coincidence in the first ten observations of the elasticity of the aqueous vapour, derived from the experiment, with the amount as determined from calculation in a range of temperature from 58° to 74°; the differences in the eleventh column being much less than I should have anticipated, even from the necessary uncertainty in ascertaining the temperature by the thermometers.

The remaining series exhibit larger and rather increasing differences, but such only as might fairly be supposed to come within the limits of errors of observation. It must also be observed that they were taken at greater intervals apart, a circumstance which I shall presently show may have had a considerable influence upon the results. The differences in the last column are, however, all, except the first, marked with the positive sign +, denoting that the depression from observation is invariably greater than that which would have resulted from the calculated elasticity of the vapour. This would rather indicate some constant error in some of the data of the calculation than the necessarily fluctuating errors of observation; and we should only have to assume the specific gravity of mercury as 13·590 instead of 13·624, and the mean difference would disappear. There can, therefore, I think, be not hesitation in coming to the conclusion that, considering the difficulty and complexity of the several adjustments, and the variety of the necessary corrections applied to the observations, the whole

arrangement was even more perfect than could have been expected, up to the time of this first register.

It was a principal object with me, as soon as possible to obtain a good and uninterrupted series of observations during a long period, taken at least once a day at some fixed hour; and for this purpose I engaged a careful workman of Mr. Newman's, who had been instructed in the reading of the different instruments, to keep a register of their indications at 7 A.M. in the summer months, and 7½ A.M. in the winter. By a careful comparison of his readings with those of others, he was found to be fully competent to the task. The following register contains these observations for one year and a half, commencing in October, 1830, and ending in March, 1832. They have been corrected in the same way as the last, and the same kind of comparison instituted. The depression of the water-barometer has been worked out daily for the first two and the last months; but for the intermediate months I have satisfied myself with making the calculation for the monthly mean results. The gradually increasing differences between this depression and the elasticity due to the vapour, have forced upon my mind the unwelcome conviction that, by some means or other, gaseous matter has crept into the instrument; and under this impression it was useless to carry the calculations further.

Register II. *Temperature and Height of the Water and Mercurial Barometers at 7 A.M. in the Summer, and 7^h 30^m A.M. in the Winter, from October, 1830, to March, 1832.*

1830.	Thermometers. In.	Thermometers. Out.	Water-Barometer	Temperature of Mercury.	Mercurial Barometer	Water-Barometer reduced to Mercury.	Difference.	Elasticity of Vapour.	Difference.
	°	°	Inches.	°	Inches.	Inches.	Inch.	Inch.	Inch.
Oct. 9	56	56	406·48	55	30·416	29·836	·580	·492	·088
10	56	56	406·85	56	30·438	29·863	·575	·492	·083
11	55·5	55	405·63	50	30·369	29·773	·596	·484	·112
12	55·5	56	404·50	53	30·231	29·690	·541	·484	·057
13	55·5	55·5	405·04	52	30·329	29·730	·599	·484	·115
14	56	56	404·50	52	30·252	29·690	·562	·492	·070
15	55	54·5	403·46	50	30·215	29·614	·601	·476	·125
16	55	54	403·93	45	30·166	29·649	·517	·476	·041
17	54	54	405·08	47	30·322	29·733	·589	·460	·129
18	53·5	53	404·52	48	30·220	29·692	·528	·452	·076
19	55	55	400·50	54·5	29·905	29·397	·508	·476	·032
20	57	57	399·89	59	29·982	29·352	·630	·508	·122
21	58	59	401·38	59	30·124	29·461	·663	·526	·137
22	61	61	402·29	62	30·279	29·528	·751	·577	·174
23	61	60·5	403·56	58	30·310	29·621	·689	·577	·112
24	57	57	405·60	52·5	30·411	29·771	·640	·508	·132
25	55	55·5	401·34	55	30·080	29·458	·622	·476	·146
26	57	56·5	399·28	52	29·897	29·307	·590	·508	·082
27	50·5	50	405·97	41	30·348	29·798	·550	·407	·143
28	53	53	399·72	54	29·938	29·339	·599	·444	·155
29	56	55	394·85	55	29·655	28·982	·673	·492	·181
30	54·5	54	399·93	52·5	29·945	29·354	·591	·460	·131
31	54	53·5	399·32	54	29·901	29·310	·591	·460	·131
Means	55·7	55·5	402·77	52·8	30·162	29·563	·599	·476	·123
Nov. 1	56	56	401·18	57	30·066	29·446	·620	·492	·128
2	57	56·5	401·38	57	30·095	29·461	·634	·508	·126
3	56·5	56·5	398·75	57·5	30·009	29·268	·741	·500	·241
4	57	57	397·07	56	29·773	29·145	·628	·508	·120
5	56	55·5	399·11	56 5	29·897	29·294	·603	·492	·111
6	57	57	393·90	58	29·574	28·912	·662	·508	·154
7	57·5	57	388·51	58	29·093	28·516	·577	·517	·060
8	57	57	394·79	54·5	29·602	28·978	·624	·508	·116
9	55	54	398·74	52	29·855	29·266	·589	·468	·121
10	53	53	397·55	53	29·772	29·180	·592	·444	·148
11	55·5	55	394·61	55	29·498	28·964	·534	·476	·058
12	53	53	399·61	44·5	29·913	29·332	·581	·444	·137
13	51	51	399·24	52·5	29·863	29·304	·559	·414	·145
14	55	55	394·90	54·5	29·574	28·985	·589	·476	·113
15	54·5	54	394·60	54	29·492	28·964	·528	·460	·068
16	55·5	55	391·38	55	29·347	28·727	·620	·476	·144
17	55	55	392·66	54	29·420	28·821	·599	·476	·123

1830.	Thermometers. In.	Thermometers. Out.	Water-Barometer	Temperature of Mercury.	Mercurial Barometer	Water-Barometer reduced to Mercury.	Difference.	Elasticity of Vapour.	Difference.
	°	°	Inches.	°	Inches.	Inches.	Inch.	Inch.	Inch.
Nov. 18	51	51	397·43	54	29·708	29·171	·537	·414	·123
19	52	52·5	402·97	50	30·156	29·578	·578	·428	·150
20	50·5	50	401·41	51	30·022	26·463	·559	·400	·159
21	50	49	400·01	52	29·904	29·367	·537	·394	·143
22	54	53	396·61	54	29·596	29·111	·485	·468	·017
23	53	53	402·18	52	30·115	29·520	·595	·444	·151
24	50·5	51	406·07	50	30·380	29·805	·575	·407	·168
25	47·5	47	406·68	47	30·368	29·850	·518	·364	·154
26	49	49	403·23	47·5	30·153	29·597	·556	·388	·168
27	48·5	49	398·00	49	29·760	29·213	·547	·388	·159
28	46·5	46	394·91	48·5	29·485	28·986	·499	·352	·147
29	49	48	398·15	50	29·741	29·223	·518	·382	·136
30	49	49	399·71	50	29·884	29·339	·545	·388	·157
Means	53·1	52·8	398·18	52·8	29·770	29·226	·544	·444	·100
Dec. 1	50·5	50	401·04	50	29·993				
2	48	48	399·52	49	29·857				
3	49	48	396·06	49	29·505				
4	47·5	47	397·97	48	29·717				
5	47·5	47	398·33	46	29·784				
6	47	47	389·76	49	29·121				
7	50	49	388·73	50	29·118				
8	55	55	390·13	50	29·175				
9	48	48	386·57	50	28·927				
10	51	51	387·49	50	28·992				
11	45·5	46	392·29	47	29·286				
12	43	43	393·99	47	29·374				
13	40	39·5	404·81	44	30·170				
14	43	43	407·13	46	30·394				
15	44	43	408·03	48	30·526				
16	43	43	406·57	48	30·334				
17	40·5	40	403·23	45	30·066				
18	40	40	404·37	43	30·172				
19	41·5	41	405·12	45	30·208				
20	43	43	395·23	47	29·475				
21	45	45	395·67	48·5	29·525				
22	47·5	47	396·11	50	29·576				
23	42	42	394·44	48	29·415				
24	34·5	36	392·90	41	29·455				
25	37	37	393·50	34	29·311				
26	36·5	36	393·95	40	29·347				
27	39	39	392·21	42	29·806				
28	40	40	389·81	44	29·048				
29	42	42	397·53	43	29·665				
30	42·5	43	395·13	45	29·488				
31	45	45	390·59	49	29·158				
Means	44·1	44	396·39	46·3	29·613	29·094	·519	·328	·191

1831.	Thermometers.		Water-Barometer	Temperature of Mercury.	Mercurial Barometer	Water-Barometer reduced to Mercury.	Difference.	Elasticity of Vapour.	Difference.
	In.	Out.							
	°	°	Inches.		Inches.	Inches.	Inch.	Inch.	Inch.
Jan. 1	46	45	398·23	48	29·743				
2	46	46	399·31	50	29·825				
3	46	46	399·73	49	29·872				
4	47	47	399·29	48	29·862				
5	45	45	399·21	49	29·820				
6	47	47	403·73	47	30·170				
7	44·5	44	409·19	45	30·578				
8	41·5	41	409·79	44	30·604				
9	42	42	405·45	46	30·269				
10	45	45	400·12	48	29·882				
11	44	44	402·56	48	30·156				
12	45	44·5	402·64	47	30·078				
13	44	44	403·15	44	30·088				
14	44·5	44	403·63	48	30·157				
15	42·5	42	401·93	46	29·968				
16	41	41	399·75	45	29·832				
17	43·5	43	396·63	46	29·518				
18	45	45	395·43	46	29·548				
19	48	48	396·30	50	29·617				
20	46·5	46	393·65	50	29·425				
21	48	48	389·21	47	29·117				
22	50	50	389·94	52	29·187				
23	50	50	390·93	53	29·274				
24	46·5	46	394·44	49	29·455				
25	45·5	45	398·27	47	29·756				
26	39·5	39	403·22	44	30·069				
27	43	43	401·89	41	30·049				
28	43·5	43	396·85	46	29·530				
29	42	42	400·17	48	29·863				
30	41·5	41	399·75	45	29·830				
31	42	42	398·53	45	29·753				
Means	44·7	44·5	399·45	46·9	29·835	29·319	·516	·340	·176
Feb. 1	42	41·5	390·61	44	29·177				
2	42	42	390·08	44	29·188				
3	41	41	394·31	44	29·431				
4	45·5	45	388·04	48	29·031				
5	43	43	396·29	47	29·580				
6	43·5	43	400·59	46	29·931				
7	45·5	45	394·46	48	29·490				
8	49	49	398·68	52	29·849				
9	51·5	51	399·35	53	29·723				
10	53	53	402·21	54	30·169				
11	55	55	402·07	55	30·196				
12	53	53	402·82	56	30·230				
13	53·5	53	402·47	56	30·212				
14	54	54	402·17	53	30·169				
15	53	53·5	401·18	50	30·056				

1831.	Thermometers. In	Thermometers. Out	Water Barometer	Temperature of Mercury	Mercurial Barometer	Water Barometer reduced to Mercury	Difference	Elasticity of Vapour	Difference
	°	°	Inches.	°	Inches	Inches.	Inch.	Inch.	Inch.
Feb. 16	52	52	397·86	51	29·825				
17	50 5	50	398·95	52	29·876				
18	48	47	403·08	51	30·172				
19	48	48	401·28	51	30·050				
20	48	47 5	399 87	47	29·935				
21	45	44 5	401 63	48	30·045				
22	43	43	401·47	47	29·995				
23	44·5	44	406·16	42 5	30·389				
24	45 5	45	403·14	47	30 158				
25	49	48	397 98	50	29 820				
26	47	47 5	391 20	50	29·209				
27	46 5	46	391·74	49	29 325				
28	46	46	394 59	46	29 526				
Means	47·8	47·5	398 35	49·2	29 813	29 239	·574	·376	·198
Mar. 1	44	43 5	398·94	48	29·810				
2	46·5	46	397·56	50	29·763				
3	51·5	51	394 41	53	29·582				
4	53	52·5	395 64	54	29·676				
5	52·5	52	397·23	55	29·818				
6	53	53	389·37	55	29·167				
7	52	51·5	384·48	54	29·581				
8	49	48 5	397·12	53	29·773				
9	50	50	394·19	53	29·528				
10	48	48	396·83	50	29·871				
11	53·5	53	396 05	54	29·724				
12	49 5	49	398 94	53	29·907				
13	50·5	50	394·99	52	29·682				
14	50	49·5	395·42	52	29·644				
15	48 5	48	397 20	51	29·767				
16	52	52	304 50	53	29 566				
17	54·5	54	396·88	56	29·816				
18	54·5	54	401·01	55	30 130				
19	49	49	402·48	51	30·194				
20	50	50·5	400·92	45	30·037				
21	52·5	52	400·18	53	30·044				
22	51·5	51·5	402·42	47	30·199				
23	48	48	404·55	49	30·347				
24	44·5	44	401·02	47	30 031				
25	44	44	396·11	47	29·656				
26	46	46	391 73	48	29·342				
27	49·5	49	397·82	51	29·838				
28	51	51	399 74	48	29·994				
29	50	50·5	431·41	45	30·127				
30	48	48	403 08	43	30·232				
31	47	47	404·82	48	30·352				
Means	49·8	49 5	397·71	50 8	29·843	29·191	·652	·400	·252

1831.	Thermometers. In.	Thermometers. Out.	Water-Barometer	Temperature of Mercury.	Mercurial Barometer	Water-Barometer reduced to Mercury.	Difference.	Elasticity of Vapour.	Difference.
	°	°	Inches.	°	Inches.	Inches.	Inch.	Inch.	Inch.
April 1	47·5	47	404·81.	50	30·422				
2	45·5	45	401·11	49	30·045				
3	46	46	399·65	49	29·944				
4	46·5	46	396·43	50	29·604				
5	45·5	45	393·76	49	29·484				
6	49	49	392·98	50	29·462				
7	49	49	391·51	47	29·382				
8	52	52	388·58	54	20·220				
9	51	51	393·19	54	29·434				
10	53	53	393·14	55	29·530				
11	54	54	397·99	55	29·909				
12	54	54	397·36	53	29·883				
13	56	56	390·32	53	29·883				
14	57	57	389·75	54	29·873				
15	54·5	54	398·48	55	29·971				
16	56	56	390·50	54	30·003				
17	56	56	389·81	53	29·933				
18	52	52	399·43	53	30·016				
19	52·5	52	398·12	48	29·924				
20	52	52	396·51	51	29·697				
21	53	53	392·91	49	29·544				
22	54	54	390·97	52	29·407				
23	56	56	391·69	52	29·470				
24	55·5	55	395·42	53	29·762				
25	55	55	397·95	53	29·943				
26	55	55	395·82	52	29·795				
27	56	56	393·48	53	29·620				
28	55·5	55	390·49	52	29·324				
29	55	55	397·83	51	29·185				
30	56	56	390·84	56	29·397				
Means	52·7	52·5	394·69	51·9	29·702	28·970	·732	·432	·300
May 1	55	55	390·86	54	29·400				
2	56	56	391·74	52	29·479				
3	55·5	55	393·00	53	29·568				
4	56	56	389·84	57	29·587				
5	54	54	392·22	48	29·484				
6	51	51	395·38	52	29·685				
7	48·5	49	399·25	51	20·974				
8	48·5	49	402·21	52	30·203				
9	50	50	433·55	52	30·285				
10	52	52	401·01	54	30·163				
11	51	51	400·00	53	30·136				
12	54	54	399·95	55	30·100				
13	55	55	397·28	52	29·919				
14	51	54	399·01	48	30·026				
15	51·5	52	398·93	47	30·001				
16	54	54	399·43	50	30·064				

1831.	Thermometers. In.	Thermometers. Out.	Water-Barometer	Temperature of Mercury.	Mercurial Barometer	Water-Barometer reduced to Mercury.	Difference.	Elasticity of Vapour.	Difference.
	°	°	Inches.	°	Inches.	Inches.	Inch.	Inch.	Inch.
May 17	56	56	400·05	55	30·153				
18	58	58	397·53	57	29·994				
19	58·5	58	394·23	57	29·753				
20	61	61	393·49	61	29·639				
21	60·5	60	394·90	59	29·827				
22	59·5	60	396·66	58	29·950				
23	59	59	395·19	57	29·846				
24	61	61	393·88	60	29·785				
25	62	62	393·77	61	29·771				
26	61	61	394·35	58	29·802				
27	59	59	393·66	55	29·736				
28	58·5	59	395·44	57	29·841				
29	58	58·5	396·31	56	29·913				
30	57	57	395·69	55	29·838				
31	57	57	396·99	55	29·930				
Means	55·9	55·9	397·28	54·5	29·866	29·161	·705	·492	·213
June 1	57	57	395·59	57	29·843				
2	58	58	398·21	55	30·063				
3	58	58	398·54	55	30·100				
4	59	59	390·52	56	30·130				
5	60	60	397·47	59	30·058				
6	59	59	390·01	56	29·900				
7	58	58	390·30	55	30·010				
8	57	57	394·58	55	29·787				
9	58	57·5	394·47	56	29·795				
10	60	60	392·25	59	29·642				
11	60	60	390·64	60	29·539				
12	62	62	392·31	62	29·709				
13	62	62	393·72	61	29·791				
14	62·5	62	397·07	61	30·076				
15	62	62	394·76	62	29·827				
16	61	61	393·50	60	29·775				
17	61	61	394·48	59	29·864				
18	61	61·5	395·65	60	29·946				
19	63	63	394·08	63	29·848				
20	61·5	61	397·53	59	30·101				
21	62	62	397·63	60	30·129				
22	63	62·5	397·32	61	30·128				
23	64	64	397·11	66	30·129				
24	63·5	63	394·51	59	29·915				
25	61·5	61·5	392·59	60	29·718				
26	59·5	60	390·85	58	29·568				
27	59	59	390·60	57	29·873				
28	60	60	393·94	59	29·814				
29	59·5	59·5	395·83	58	29·954				
30	59·5	59·5	395·49	58	29·926				
Means	60·4	60·3	394·52	58·9	29·897	28·952	·945	·560	·385

1831.	Thermometers. In.	Thermometers. Out.	Water-Barometer	Temperature of Mercury.	Mercurial Barometer	Water-Barometer reduced to Mercury.	Difference.	Elasticity of Vapour.	Difference.
	°	°	Inches.	°	Inches	Inches.	Inch.	Inch.	Inch.
July 1	60	60	396·67	59	30·030				
2	61	61	395·55	59	29·959				
3	62	62	394·97	61	29·935				
4	62·5	62·5	397·17	61	30·126				
5	64	64	397·06	63	30 165				
6	65	64·5	398·21	64	30·259				
7	64·5	64·5	398·23	63	30·269				
8	64	64	397·16	62	30·167				
9	65	64·5	396·03	63	30·093				
10	68	68	393·38	67	29·977				
11	63·5	63·5	392·76	62	29·832				
12	65	65	389·30	64	29·586				
13	64	64·5	389·02	63·5	29·627				
14	63	62·5	390·74	63	29·668				
15	62	62·5	391·02	62	29·679				
16	62·5	62·5	391·23	63	29·697				
17	62	62·5	393·50	63	29·878				
18	62·5	62	394·58	62·5	29·956				
19	62·5	62	393·18	62·5	29·860				
20	63	62·5	391·65	62·5	29·750				
21	64·5	64	389·78	65	29·626				
22	62	61·5	392·13	63	29·756				
23	62·5	62	392·10	63	29·768				
24	61·5	61·5	391·80	60	29·730				
25	63	62·5	394·73	61	29·985				
26	63	62·5	396·11	61·5	30·097				
27	65	64·5	396·30	63	30·166				
28	67·5	67	394·68	68	30·097				
29	67·5	67	394·02	66	30·034				
30									
31									
Means	63·5	63·3	393·90	62·7	29·923	28·912	1·011	·636	·475
Aug. 1									
2	67	67	391·40	66·5	29·831				
3	67·5	68	390·84	67	29·818				
4	67	67	390·32	66	29·756				
5	68·5	69	398·14	68	29·603				
6	67	66·5	399·34	64	29·655				
7	66	66·5	398·75	66	29·603				
8	66	66	390·45	64	29·739				
9	68	68	391·54	67	29·870				
10	68	68	392·50	65·5	29·950				
11	67	67	394·74	64·5	30·072				
12	66	66	394·64	63	30·083				
13	66·5	67	393 30	64·5	30·003				
14	66	66	392·89	63	29·946				
15	65·5	65	393·95	62	30·026				
16	66	66	394·10	63	30·061				

1831.	Thermometers. In.	Thermometers. Out.	Water-Barometer	Temperature of Mercury.	Mercurial Barometer	Water-Barometer reduced to Mercury.	Difference.	Elasticity of Vapour.	Difference.
	°	°	Inches.	°	Inches.	Inches.	Inch.	Inch.	Inch.
Aug. 17	65	65·5	393·46	64	29·992				
18	64·5	64	392·67	60	29·895				
19	62	62	389·78	61	29·646				
20	62	62	388·25	60·5	29·516				
21	63·5	64	393·94	63·5	29·986				
22	63	62·5	396·87	61	30·266				
23	64·5	64·5	395·26	63·5	30 125				
24	64·5	65	392·66	63	29·925				
25	65·5	64·5	389·00	63	29·618				
26	62	62	393·03	59·5	29·885				
27	63·5	64	392·45	64	29·889				
28	65	64·5	393·91	60·5	30·004				
29	63	62·5	395·89	59·5	30·141				
30	64·5	64·5	394·55	62	29·876				
31	66	66	391·42	66	29·880				
Means	65·3	65·3	393·33	62·0	29·889	28·870	1·019	·657	·462
Sept. 1	63	62·5	392·65	60	29·887				
2	59	59	392·13	54	29·767				
3	58	58	393·51	53	29·852				
4	58	58	392·56	54	29·786				
5	62	62	392·11	63	29·721				
6	64	63·5	391·94	64	29·846				
7	61	60·5	392·48	56	29·835				
8	58·5	58	390·97	54	29·656				
9	57	57	389·34	53	29·541				
10	57·5	58	392·14	66·5	29·720				
11	57	57·5	394·18	56	29·908				
12	58·5	59	396·36	59	30·101				
13	59	59·5	396·79	57·5	30·159				
14	59·5	60	395·80	59	30·071				
15	59	59	396·24	56	30·100				
16	59	59	396·76	59	30·150				
17	59	59·5	397·09	58	30·190				
18	59	59	395·54	58	30·069				
19	59·5	59	397·32	58	29·884				
20	57·5	58	392·70	52	29·798				
21	58·5	59	391·64	59	29·745				
22	59	59	393·04	56·5	29·857				
23	58	57·5	395·68	55	30 029				
24	59·5	59·5	396·70	59·5	30·152				
25	60	60	394·59	59	30·001				
26	61	61	393·83	61	29·958				
27	61	61	392·83	60	29·855				
28	62	61·5	390·77	60	29·680				
29	62·6	62·5	388·51	62	29·577				
30	63	63	387·34	62·5	29·502				
Means	59·6	59·7	393·45	58·1	29·880	28·879	1·001	·560	·441

1831.	Thermometers. In.	Thermometers. Out.	Water-Barometer	Temperature of Mercury.	Mercurial Barometer	Water-Barometer reduced to Mercury.	Difference.	Elasticity of Vapour.	Difference.
	°	°	Inches.	°	Inches.	Inches.	Inch.	Inch.	Inch.
Oct. 1	63·5	63·5	384·11	63·5	29·236				
2	63	62·5	384·94	62	29·269				
3	62	62	389·45	60	29·610				
4	62	62	390·52	61	29·689				
5	61·5	61	392·07	59	29·805				
6	59·5	59·5	393·23	59	29·874				
7	62	61·5	390·60	63	29·711				
8	63	62·5	389·55	61·5	29·658				
9	61	60·5	389·73	57	29·613				
10	59·5	60	399·31	59	29·558				
11	61	61·5	389·92	61	29·629				
12	60	60·5	390·61	61	29·694				
13	60·5	60·5	390·00	60	29·641				
14	63	62·5	388·20	64	29·538				
15	62	62	390·61	63	29·605				
16	60	60·5	395·63	60	30·091				
17	58·5	58	398·59	54·5	30·288				
18	60	60	398·98	59	30·354				
19	60·5	60	397·06	59	30·213				
20	61	60·5	393·84	59	20·937				
21	60	60	398·94	58	29·866				
22	57	57	395·53	52	30·007				
23	59	59	393·77	60	29·918				
24	59	59	395·23	57·5	30·031				
25	57·5	58	393·34	56·5	29·878				
26	59	59	388·33	59·5	29·477				
27	58·5	59	390·75	58·5	29·672				
28	58	58	394·47	57	29·946				
29	57·7	58	398·09	57·5	30·260				
30	56·5	56·5	398·53	52·5	30·265				
31	57·5	56·5	397·22	56	30·165				
Means	60	60	392·75	59	29·824	28·827	·997	·560	·437
Nov. 1	57	57	395·11	57	30·002				
2	57	57	391·77	58	29·722				
3	51·5	51	389·52	54	29·473				
4	49·5	49	392·97	50	29·696				
5	51	50·5	390·70	51·5	29·557				
6	51·5	51·5	391·43	51	29·616				
7	53	52·5	388·99	52	29·431				
8	51·5	51	391·36	52·5	29·601				
9	52	51·5	397·31	50·5	30·086				
10	51	51	401·12	45	30·416				
11	50	50	398·83	50	30·212				
12	53·5	53	399·17	54	30·278				
13	52·5	52·5	395·39	50·5	29·963				
14	50	50	392·11	48	30·064				
15	50	49·5	390·05	49·5	29·476				
16	44	44	388·37	46·5	29·283				

1831.	Thermometers. In.	Thermometers. Out.	Water-Barometer	Temperature of Mercury.	Mercurial Barometer	Water-Barometer reduced to Mercury.	Difference.	Elasticity of Vapour.	Difference.
	°	°	Inches.	°	Inches.	Inches.	Inch.	Inch.	Inch.
Nov. 17	43	43	392·17	45	29·539				
18	42	42·5	393·49	43	29·669				
19	43	43	390·26	45	29·420				
20	42·5	42·5	394·93	45	29·761				
21	48	48	392·17	48·5	29·621				
22	51·5	51	393·77	52·5	29·807				
23	54	53·5	394·86	55	29·932				
24	54·5	55	395·30	55	29·973				
25	55	55	394·51	56	29·931				
26	56	56	393·74	56·5	29·888				
27	54	54	398·74	53	30·245				
28	48·5	48	402·41	48	30·468				
29	46·5	46	403·07	50	30·522				
30	46	45·5	400·95	45·5	30·343				
Means	50·3	50·1	394·49	50·7	29·866	28·995	·911	·400	·511
Dec. 1	48	48	398·17	50·5	30·135				
2	50·5	50	396·35	52	30·021				
3	52	51·5	397·29	52·5	30·120				
4	51	50·5	396·25	51·5	30·013				
5	51·5	51·5	393·73	52·5	29·814				
6	52	52	388·33	53	29·385				
7	53	53	382·21	54·5	28 962				
8	54	54	384·41	55·5	29·124				
9	56	56	384·33	57·5	29·139				
10	55·5	55	387·54	57	29·366				
11	56	56	386·65	57·5	29·315				
12	56·5	56	386·64	56	29·308				
13	56·5	56	386·66	57	29·306				
14	56	56	389·44	55·5	29·539				
15	55	55	382·29	51	29·740				
16	54	54	383·35	50	29·820				
17	52·5	52	391·95	52	29·674				
18	53	53	387·43	54	29·330				
19	51	50·5	390·15	50	29·507				
20	51	51	393·95	53·5	29·760				
21	52	52	391·01	53	29·623				
22	49·5	49	394·33	48	29·853				
23	49	49	393·42	48	29·765				
24	47	46·5	399·04	50	30·196				
25	44	43·5	400·99	41	30·346				
26	43	43	400·30	46	30·261				
27	44	44	401·82	45	30·435				
28	44·5	44	401·85	46	30·416				
29	46	45·5	400·46	47	30·320				
30	46·5	46	399·15	46	30·210				
31	45·5	45	399·43	44·5	30·221				
Means	50·5	50·6	392·51	51·2	29·775	28·786	·989	·414	·575

1832.	Thermometers. In.	Thermometers. Out.	Water-Barometer	Temperature of Mercury.	Mercurial Barometer	Water-Barometer reduced to Mercury.	Difference.	Elasticity of Vapour.	Difference.
	°	°	Inches.	°	Inches.	Inches.	Inch.	Inch.	Inch.
Jan. 1	44	44	399·60	41	30·236				
2	44·5	44	399·61	43	29·977				
3	43	43	394·88	45	29·822				
4	44	43·5	393·58	43	29·531				
5	42·5	42	392·[illegible]	41	29·661				
6	43·5	43	391·45	46	29·558				
7	45	45	389·03	46·5	29·404				
8	45·5	45	389·14	49	29·383				
9	46	46	390·37	49	29·484				
10	48·5	48	391.17	50	29·566				
11	50	50	393·33	53	29·781				
12	50	49·5	393·63	52	29·801				
13	50	50	393·62	49	29·574				
14	48	48	397·77	45	30·119				
15	46·5	46	401·79	44	30·436				
16	45	45	402·23	47	30·467				
17	47	47	400·43	47	30·333				
18	48·5	48	400·21	51	30·337				
19	48	48	400·42	48	30·332				
20	45	45	398·77	41	30·173				
21	46·5	46	398·64	46·5	30·178				
22	48	48	399·08	49	30·235				
23	48·5	48	399·65	47	30·284				
24	47	47	399·18	49	30·225				
25	49	49	393·79	50	29·808				
26	48	48	394·18	48·5	29·844				
27	49	48·5	395·10	46	29·905				
28	45·5	45	399·47	43	30·235				
29	47	47	398·53	48	30·184				
30	48	48	399·93	48	30·317				
31	49·5	49	397·03	50	30·146				
Means	46·8	46·6	396·38	47	29·979	29·094	·885	·364	·521
Feb. 1	48	48	390·22	47	29·523				
2	50·5	50	386·22	51	29·218				
3	50	49·5	389·46	46	29·459				
4	50·5	50	393·41	51	29·797				
5	52	52	395·35	53·5	29·983				
6	53·5	53	393·10	54·5	29·816				
7	52	52	394·16	50	29·888				
8	49·5	49	399·63	52	30·301				
9	51	51	400·04	52	30·364				
10	50	49·5	402·41	50	30·542				
11	50	49·5	400·21	49	30·350				
12	48	47·5	397·94	51·5	30·154				
13	48	47·5	397·18	49	30·073				
14	47	47	396·80	50·5	30·054				
15	46	44·5	397·37	48	30·060				

1832.	Thermometers. In.	Thermometers. Out.	Water-Barometer	Temperature of Mercury.	Mercurial Barometer	Water-Barometer reduced to Mercury.	Difference.	Elasticity of Vapour.	Difference.
	°	°	Inches.	°	Inches.	Inches.	Inch.	Inch.	Inch.
Feb. 16	43	42·5	395·17	41·5	29·867				
17	45	45	393.02	48	29·708				
18	46	46	398·35	49	30·165				
19	47	46·5	400·02	50	30·307				
20	46	46·5	400·11	46	30·325				
21	46	45·5	399·43	48	30·263				
22	44	44·5	400·42	49	30·324				
23	44	44	400·05	43	30·380				
24	43	43	398·89	46	30·168				
25	42	42	397·21	43	30·019				
26	43	42·5	399·22	43·5	30·213				
27	46	46	397·72	44	30·112				
28	44·5	44	398·80	48	30·104				
29	44	44	398·91	48	30·193				
Means	47·2	47	396·92	48·3	30·060	29·133	·927	·364	·563
Mar. 1	44	44·5	399·85	46	30·280	29·349	·931	·328	+·603
2	47	47	399·83	49	30·299	29·348	·951	·364	+·587
3	46	46·5	399·82	47	30·305	29·346	·959	·352	+·607
4	48	47·5	396·26	48	30·018	29·085	·933	·376	+·557
5	48·5	48	393·23	49·5	29·770	28·864	·906	·376	+·530
6	47	46·5	394·16	49	29·829	28·916	·913	·364	+·549
7	48	48	388·58	49	29·391	28·521	·870	·376	+·494
8	45	45	390·14	45	29·486	28·636	·850	·340	+·510
9	44·5	44	396·73	45	30·008	29·120	·888	·328	+·560
10	45	45	401·05	48	30·377	29·437	·940	·340	+·600
11	44	44	398·98	43·5	30·205	29·285	·920	·328	+·592
12	44	44·5	397·03	48	30·042	29·142	·900	·328	+·572
13	45	45	394·79	48	29·920	28·978	·942	·340	+·602
14	47	46·5	390·16	49	29·507	28·637	·870	·364	+·506
15	46·5	46	388·45	49·5	29·360	28·512	·848	·352	+·496
16	47·5	47	393·83	43	29·816	28·907	·909	·364	+·545
17	50	49·5	388·53	50·5	29·415	28·518	·897	·400	+·497
18	49	48·5	389·91	49	29·503	28·619	·884	·388	+·496
19	48	48	394·17	47·5	29·847	28·932	·915	·376	+·539
20	50	50	389·41	50	29·492	28·583	·909	·400	+·509
21	50	50	395·59	51·5	29·995	29·036	·959	·400	+·559
22	51	50·5	397·12	52·5	30·128	29·148	·980	·414	+·566
23	52	52	394·76	54	29·961	28·975	·986	·428	+·558
24	52	51·5	393·15	47·5	29·818	28·857	·961	·428	+·533
25	47·5	47·5	397·31	50·5	30·117	29·162	·955	·364	+·591
26	48	48	397·86	51	30·164	29·203	·961	·376	+·585
27	50	50	395·87	47·5	30·010	29 057	·953	·400	+·553
28	48	48·5	396·94	52	30·090	29·135	·955	·376	+·579
29	49	49	395·68	47·5	29·989	29·042	·947	·388	+·559
30	49·5	49	394·89	51·5	29·972	28·985	·987	·388	+·599
31	50	50	393·31	52	29·824	28·869	·955	·400	+·555
Means	47·8	47·6	394·75	48·7	29·901	28·974	·927	·376	+·551

It will be observed how very gradually the differences, recorded in the last columns of the months, increase; till, in the month of March, 1832, they average ·551; more than half an inch of mercury, indicating a mean depression of the water-barometer of more than seven inches. This result is further confirmed by a comparison of the monthly mean heights of the two instruments, and by observing that in the month of March, 1832, when the differences for each day are exhibited, the greatest differences occur with the highest barometer, as would happen from the greater compression of included air under such circumstances. The regularity of this secondary effect is indeed very remarkable.

This unfortunate result not being doubtful, I determined to open the boiler for the purpose of throwing some light, if possible, upon the cause. Dr. Prout, to whose valuable advice I have been greatly indebted in all the previous arrangements, did me the favour of assisting at this examination.

Upon removing the cover, we found that a portion of the liquid had by some means escaped, as, although the column of water stood considerably below the neutral point, the ivory point was not in contact with it. We carefully measured its distance, and found it to be 0·3 inch, to which, as the barometer stood at 385·94 inches, must be added 0·05 inch for the difference from the neutral point; and the amount 0·35 inch will be the quantity of the fluid deficient.

Upon examining the oil upon the surface, we found that it had undergone a very remarkable change. It

was nearly covered with large clots of a mucilaginous-looking substance, which, in places, reached quite through to the water beneath; so that upon moving them aside the latter was uncovered. Upon the top of this, in various parts, were drops of an aqueous fluid, of a tenacious consistence, which had a very decided sweet taste, and resembled the substance which is formed during the process of saponification, to which the name of Glycerine has been given. There was also some carbonaceous matter, but not more than might probably be accounted for from depositions from the atmosphere. All these matters, with a great portion of the remaining oil, were carefully skimmed off, and the water beneath was found perfectly bright and transparent; there were no signs of metallic corrosion in any part; and every portion of the boiler, with its cover and brass-work, was as bright as on the day when they were put together.

We next examined the portion of oil and water which had been set by in a glass vessel for the purpose of watching any changes which it might undergo. This we found in a very different state. The stratum of oil upon the surface was rather more than an inch thick, and in this it differed from that in the boiler, which was not more than half an inch. The great body of it was perfectly bright and pure, and did not seem, from its taste, to have undergone any change, or to have acquired any rancidity. At the point of contact with the water it appeared to have undergone change, and to be separated from it by a tough film of the same mucilaginous-looking substance which we had found in the

boiler. Upon agitating the glass, this film could be bent upwards without breaking; and a kind of fold was made in it of so tenacious a quality as to be some time before it again accommodated itself to the level of the liquid. Upon examination with a lens it appeared to contain minute air-bubbles. These air-bubbles may have originated from some decomposition of the oil or water; but they were by no means numerous, and it is not at all improbable that they were the remains of a thin stratum of air included between the oil and the water; as there would be no perfect contact between the two liquids near the surface of the water. We next placed the glass, with its contents, under the receiver of an air-pump, and upon exhaustion of the air these little bubbles expanded and seemed to lift the film in parts, and to escape with some difficulty through the oil. No air-bubbles, however, were formed in the mass of the subjacent water; proving that the water had been, in this instance, protected by the oil. Upon pushing the exhaustion to the utmost, a few insignificant bubbles were indeed extricated from a small flock of dust which had fallen to the bottom of the glass.

A little of the water was then taken out of the boiler in a glass vessel, which still retained a thin stratum of oil upon its surface. Upon exposing this to the action of the pump, air-bubbles in abundance were extricated from the whole mass, and it swelled up so as nearly to overflow the vessel in which it was contained; presenting a very marked contrast to the result of the previous experiment, and proving that the

water in the boiler must have been strongly impregnated with gaseous matter. This examination took place on the 13th June, almost exactly two years from the completion of the water-barometer.

Upon consideration of all the circumstances, we were of opinion that the formation of the mucilaginous-looking matter had opened a permeable communication between the water in the boiler and the atmosphere; by which not only the water was carried off by evaporation, which would account for the deficiency, but the air passed in and was absorbed: and we have little doubt that if the stratum of oil had been thicker, the change would have been confined to the lower surface, and the water would have been perfectly protected, as was the portion set aside in the glass.

I shall now proceed to notice two or three more circumstances of interest, which I remarked during my observation of the water-barometer.

It is extremely curious to watch its action in windy weather; the column of water appears to be in a perpetual motion, resembling the slow action of respiration. During a heavy gale of wind on the 16th of November, 1830, I made the following observations:—

Time.	Thermometers.		Water-Barometer.	Mercurial Barometer.
	Internal.	External.		
h m	°	°	Inches.	Inches.
2 30	56	55·5	387·87	29·092
2 45	....	....	387·59	29·090
3 0	....	....	387·44	29·090
3 15	....	....	387·28	29·090
4 0	....	....	387·64	29·090
4 15	....	....	387·85	29·090

About half-past 2, the maximum range of the oscillations was about 0·28 inch; about half an hour later, one gust of wind caused an oscillation of 0·43 inch, and the minor oscillations were generally nearer the lower than the higher extreme. At 4 o'clock the movement became sensibly less in extent, and the mean point of the oscillations began to rise, and, as I ventured to predict, the wind very soon began to abate. It became very suddenly calm, and the next day was very fine. The time of this change, as indicated by the instrument, was certain within five minutes.

On the subjoined scale (Plate XX.) I have laid down the hourly observations of Mr. Hudson of the water and mercurial barometers obligingly communicated to me by that gentleman. They have not been corrected; but the corrections would be of little importance in the rough comparison which I at present design to institute. A very slight examination will show that there are many considerable oscillations of the aqueous column which are totally lost in the mercurial, and will prove that much curious information

with regard to atmospheric changes might be derived from a long-continued series of such observations.

The most important result, however, and that which alone would have amply repaid all the labour expended upon the subject, is the fact pointed out by the observations of Mr. Hudson, that the water-barometer precedes by one hour the barometer of half-inch bore, and the latter the mountain-barometer of 0·15-inch bore by the same interval, in their indications of the horary oscillations; showing that while philosophers are disputing about the hours of the maxima and minima, much depends upon the construction of the instruments observed; and proving the necessity, which I long ago pointed out, of making these delicate observations with instruments which have been compared with accurate and known standards. This comparative sluggishness of the mercurial barometer, when compared with the water, also proves that the difference between the two, when reduced by calculation of their specific gravities to the same expression, can only at times approximatively determine the elasticity of the included vapour; and that such determination must always be liable to a small error from this circumstance.

Should the Council of the Society hereafter come to the conclusion that there is enough of interest in the subject to induce them to prosecute it further, I am of opinion that the water-barometer might be reboiled and resealed without much risk; and I think that if a stratum of oil of four or five inches depth were afterwards poured upon the surface of the water, there would be little risk of the air again insinuating itself within it.

[The following account of the examination and re-filling of the water-barometer has been drawn up since the death of Professor Daniell, from notes taken by himself on the occasion.]

In consequence of a minute made at a meeting of the Council of the Royal Society, 14th November, 1844, requesting Professor Daniell to superintend the reboiling and adjustment of the water-barometer, he undertook the task, and on the 5th December following, the front of the case was opened and the top of the cistern removed. The column of fluid in the tube when carefully examined, appeared everywhere perfectly continuous and free from air specks.

By an observation made at this time, the height of the column was found to be 385·40 inches, the external thermometer marking a temperature of 44° F., the internal one 45°. The distance of the ivory point terminating the lower end of the scale from the surface of the oil in the cistern was 0·32 inch. To this must be added 0·06 of an inch as correction for the depression of 15 inches in the tube below the neutral point, making the amount of water that had escaped from the cistern equal to a depth of 0·38 inch. The mercurial barometer at the same time stood at 30·090, the temperature of the attached thermometer being 35·5.

The corrected height of the water-barometer would be 385·22 inches, which is equivalent to a column of mercury of 28·690 inches, making the difference between heights of the mercurial and water-barometer equal to 1·4 of an inch. By observations made

twice daily at the Royal Society between the 16th and 26th of November preceding, it appeared that the mean difference between the corrected heights of the mercurial and water-barometers amounted to 1·484 inches of mercury, which is equivalent to a column of 20·212 inches of water.

On proceeding further with the examination, the oil on the surface of the cistern was found to be covered with a black scum, from dust and dirt which had gained admission; beneath this the oil was perfectly clear and transparent down to the surface of the water, and between the two fluids a layer of thick, tough, whitish, fatty matter interposed; this layer had an uneven marbly appearance, as though it contained air-bubbles — an appearance which, on examination, was found to be deceptive.

Half-a-pint of the water was drawn off by siphon and immediately placed in the exhausted receiver of an air-pump. Minute specks of air became visible when the pressure within, as marked by the gauge, was 8 inches; but no abundant extrication of bubbles ensued till the mercury stood at 1·2. The temperature of the water at this time was 50°.

It smelled and tasted strongly of rancid castor oil, and was slightly opalescent. Half-a-pint of it was evaporated by steam heat, and left a thick oily residue amounting to 15·3 grs. This residue had a sweetish-sour nauseous taste, reddened litmus paper, and redissolved on adding to it a small quantity of water.

On more minutely examining the state of the cistern no air-bubbles could be detected in any part

below the surface, but a white light flocculent matter had deposited itself in vertical lines upon the sides of the cistern as well as more abundantly upon its bottom and angles.

By a subsequent operation the gas which had crept into the upper part of the tube was transferred into a jar. For this purpose the cover of the cistern was replaced, and a pressure of steam generated in the boiler: over the upper extremity of the tube a small water-bath was adjusted, and, on nipping off the sealed extremity of the barometer after the jar was placed over it, the included air was forced out as the column of liquid rose from the elasticity of the steam in the boiler. The gas thus collected amounted to 1·23 cubic inches. On analysis it proved to be pure nitrogen. The oxygen had been absorbed as it passed through the oil, producing the rancidity and other changes above detailed.

From these observations it was evident that castor oil was not effectual in preventing the admission of atmospheric air, its solution in the water and subsequent rise into the upper portion of the tube. Some other means, therefore, for effecting this became necessary, and it was suggested that a solution of caoutchouc in naphtha should be substituted for the oil; the naphtha, it was expected, would evaporate and leave an elastic and impermeable film of caoutchouc. Accordingly, in order to put this plan to the test, some water was well boiled, and whilst still boiling poured into a heated glass jar and immediately covered to the depth of an inch with a solution of caoutchouc in

naphtha, also heated to 212°, in the proportion of one part of the Mackintosh paste as sold in the shops to seven parts of naphtha; a viscid liquid was thus obtained, which gradually evaporated, leaving an elastic film of caoutchouc. Four weeks after the experiment commenced, the vessel was placed under a glass receiver and the air exhausted, not a bubble of air appeared, though the gauge indicated a pressure of only 0·3. As this result appeared satisfactory Mr. Daniell determined to employ the caoutchouc solution as a covering for the water in the cistern of the barometer.

On the 28th of January, 1845, the remainder of the water was drawn off, and the whole instrument thoroughly cleansed from oil, fresh distilled water was introduced, and the instrument boiled and sealed by Mr. Newman, in the manner previously so successfully employed. The column of water rose steadily, uninterrupted by specks or air-bubbles, and the temperature in the tube was sufficiently high to drive the mercury of the internal thermometer partially into the upper bulb. After the sealing, ebullition continued in the column for some time, and as the bubbles broke the liquid fell back, producing the ringing metallic sound emitted by a well-boiled water-hammer when properly agitated. Immediately that the steam was let off, the cover of the cistern was removed, and a brush dipped in the caoutchouc solution was passed round the metal at the upper surface of the water, to ensure the complete adhesion of the naphtha liquid. This solution, previously heated to 212°, was then

poured carefully over the surface to the depth of between two and three inches.

As soon as the temperature, as measured by the internal thermometer, had fallen to 70°, an observation of the heights of the mercurial and water barometer was made, but as the instrument had not attained a uniform temperature throughout its whole length, no reliance can be placed on this result.

On the following day an observation was taken to determine the neutral point of the instrument.

At this time the water stood at 394·26, the internal temperature being 43° F., the external 45°. As the neutral point previously was 400 inches, it is by the present determination taken 5·74 inches lower than in the former case; the difference in the height of the water-column, however, is thereby only affected ±·02 inch, a correction which is made as before.

The mercurial barometer at this time stood at 29·286; this when corrected is 29·280: the height of the column of water, reduced with the necessary corrections to inches of mercury, was 29·224, making a difference of 0·056 inch.

This agreement is not so close as that of the 18th June, 1830, on the first filling of the instrument; in three days the difference amounted to nearly $\frac{1}{4}$ of an inch, and it will be seen by the following Table that the difference has continued slowly to increase:

Register of the Water-Barometer after it had been refilled.

Date.	Hour.	Observed Mercurial Barometer.	Temperature of Mercury.	Corrected Mercurial Barometer.	Observed height of Water.	Inter. Temp.	Exter. Temp.	Water reduced to inches of Mercury.	Diff.	Elastic force of Vapour.	
										Galbraith	Dalton.
Jan. 29	..	29·280	39°	29·280	394·260	43°	45°	29·224	·056	·291	·305
Feb. 3	Noon.	29·866	36¼	29·878	400·21	40	40½	29·636	·242	·251	·263
4	..	30·210	40¼	30·204	403·82	42¾	42¾	29·898	·306	·270	·283
5	4	30·076	39	30·082	401·82	43½	43½	29·761	·321	·280	·294
7	11	29·964	38	29·972	400·41	42	42½	29·658	·314	·270	·283
8	3 P.M.	30·070	37	30·078	401·70	41½	42	29 742	·336	·270	·283
10	10	29·736	34¾	29·744	397·00	39½	40	29·435	·309	·242	·254
11	10	29·940	33¾	29·918	400·49	39½	39¼	29·626	·322	·242	·254
13	10	30·206	31¾	30·214	404·05	39	39	29 887	·327	·242	·254
Ap. 16	2 P.M.	30·272	46½	30·253	400·28	49	49½	29·772	·481	·361	·363
May 10	3 P.M.	29 458	52	29·426	387·90	54½	55	28·881	·545	·432	·443

Hourly observations of the instrument were carefully made for ten days, but these it has not been thought necessary to publish in full, on account of the increasing difference between the two instruments. On more than one occasion bubbles have been seen creeping up the tube, and at length bursting on the surface. It is possible that the ebullition which was not protracted for so long a time as when the instrument was first boiled, had not been carried so far as to expel the last portions of air, or it may be also that traces of naphtha have been dissolved by the water, and subsequently made their way into the tube giving off vapour whose tension does not follow the same law as that of aqueous vapour, or lastly air may by endosmosis have actually obtained admission through the film designed to exclude it.

Part of the deficiency is no doubt due to evapora-

tion of the naphtha from the solution of caoutchouc; this would soon reach its full extent, and a fresh determination of the neutral point would become necessary.

These inaccuracies it was the intention of Mr. Daniell to have corrected, by again boiling the instrument; for the operation, if performed with care, is one attended with less risk than that incurred in boiling an ordinary mercurial barometer.

ON CLIMATE:

CONSIDERED WITH REGARD TO HORTICULTURE.

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[The following Essay was read before the Horticultural Society, August 17th, 1824, who honoured it by the presentation of their Medal. It is here reprinted from their *Transactions*, with the sanction of the Council.]

THE following observations were committed to paper, and submitted to the consideration of the Horticultural Society, at the particular request of their Secretary. The author would scarcely have thought them novel or important enough for such a destination, but he defers to his judgment, and shall, at all events, have had the pleasure of complying with his wishes.

Horticulture differs from agriculture in one very material respect. The latter has for its object the fertilization of the soil by manures, and the different processes of cultivation in the manner best adapted to the peculiarities of any given climate: it concerns itself only with the growth and nourishment of such plants as are indigenous, or, by a long course of treatment, have become inured to the vicissitudes of weather incidental to a particular latitude. The former occupies a much wider field of research; it not only seeks to be conversant with the constitution of soils, but, as it aspires to the preservation and propagation of exotic vegetation, it necessarily embraces the con-

sideration of varieties of climate: and it labours, by art, to assimilate the confined space of its operations to that constitution of atmosphere which is most congenial to its charge, or to protect them at different periods of their growth from sudden changes of weather which would be detrimental to their health. Experience has anticipated theoretical knowledge in suggesting various artifices, by which these ends may be effected; a connected view of which has never, I believe, been attempted, but may prove to be not without interest and utility. The suggestions of experience may probably enlarge the conclusions of theory, while it is not impossible that the improved state of the latter may be found to furnish some assistance to the former.

The science of horticulture, with regard to climate, will be best considered in two divisions: the first comprises the methods of mitigating the extremes, or exalting the energies, of the natural climate in the open air; the second embraces the more difficult means of composing and maintaining a confined atmosphere, whose properties may assimilate with those of the natural atmosphere in intertropical latitudes. I shall commence my observations with the former.

The basis of the atmosphere has been proved to be of the same chemical composition in all the regions of the globe. All the varieties of climate will therefore be found to depend upon the modifications impressed upon it by light, heat, and moisture; and over these, art has obtained, even in the open air, a greater influence than at first sight would appear to be possible. By judicious management, the climate of our

gardens is rendered congenial to the luxurious productions of more favoured regions, and flowers and fruits from the confines of the tropics, flourishing in the open air, daily prove the triumphs of knowledge and industry.

For the complete understanding of the subject in all its bearings, and to enable us to derive all the practical advantages which such an understanding would certainly afford, it would be necessary to have a full knowledge of the peculiarities of the climate of every region of the earth; a knowledge which we are very far from yet possessing, but to which rapid advances are daily making. But above all, it seems necessary that we should understand the atmospheric variations of our own situation. These, though not constituting the greatest range with which we are acquainted, are great, and oftentimes sudden. The range of the thermometer in the shade is from 0° to 90° of Fahrenheit's scale; but under favourable circumstances the heat of the sun's rays reaches 135°: the changes of moisture extend from 1000, or saturation, to 389. Now the great object of the horticulturist is to stretch, as it were, his climate to the south, where these extremes of drought and cold never occur; and not only to guard against the injurious effects of the ultimate severity of weather, but to ward off the sudden changes which are liable to recur in the different seasons of the year. To enable us to understand the methods of effecting this end, it will be necessary to consider the means by which these changes are brought about in the general course of nature. The principal of these will be found to be, wind and radiation.

The amount of evaporation from the soil, and of exhalation from the foliage of the vegetable kingdom, depends upon two circumstances,—the saturation of the air with moisture, and the velocity of its motion. They are in inverse proportion to the former, and in direct proportion to the latter.

When the air is dry, vapour ascends in it with great rapidity from every surface capable of affording it, and the energy of this action is greatly promoted by wind, which removes it from the exhaling body as fast as it is formed, and prevents that accumulation which would otherwise arrest the process.

Over the state of saturation, the horticulturist has little or no control in the open air, but over its velocity he has some command. He can break the force of the blast by artificial means, such as walls, palings, hedges, or other screens; or he may find natural shelter in situations upon the acclivities of hills. Excessive exhalation is very injurious to many of the processes of vegetation, and no small proportion of what is commonly called *blight* may be attributed to this cause. Evaporation increases in a prodigiously rapid ratio with the velocity of the wind, and anything which retards the motion of the latter, is very efficacious in diminishing the amount of the former; the same surface, which in a calm state of the air would exhale 100 parts of moisture, would yield 125 in a moderate breeze, and 150 in a high wind. The dryness of the atmosphere in spring renders the effect most injurious to the tender shoots of this season of the year, and the easterly winds especially are most to

be opposed in their course. The moisture of the air flowing from any point between N E. and S.E. inclusive is to that of the air from the other quarter of the compass, in the proportion of 814 to 907 upon an average of the whole year; and it is no uncommon thing in spring for the dew-point to be more than 20 degrees below the temperature of the atmosphere in the shade, and I have even seen the difference amount to 30 degrees. The effect of such a degree of dryness is parching in the extreme, and if accompanied with wind is destructive to the blossoms of tender plants. The use of high walls, especially upon the northern and eastern sides of a garden, in checking this evil, cannot be doubtful, and in the case of tender fruit-trees, such screens should not be too far apart.

And here theory would suggest another precaution, which, I believe, has never yet been adopted, but which would be well worthy of a trial. When trees are trained upon a wall with a southern aspect, they have the advantage of a greatly exalted temperature; but this temperature, in spring, differs from the warmth of a more advanced period of the year, or of a more southern climate, in not being accompanied by an increase of moisture. In the extremely dry state of the atmosphere to which I am now alluding, the enormous exhalation from the blossoms of tender fruit-trees, which must thus be induced, cannot fail of being extremely detrimental; the effect of shading the plants from the direct rays of the sun should therefore be ascertained. The state of the weather to which I

refer, often occurs in April, May, and June, but seldom lasts many hours. Great mischief, however, may arise in a very small interval of time, and the disadvantage of a partial loss of light cannot be put in comparison with the probable effect which I have pointed out.

During the time in which I kept a register of the weather, I have seen in the month of May the thermometer in the sun at 101°, while the dew-point was only 34°; the state of saturation of the air, upon a south wall, consequently only amounted to 120, a state of dryness which is certainly not surpassed by an African Harmattan. The shelter of a mat on such occasions, would often prevent the sudden injury which so frequently arises at this period of the year.

Some of the present practices of gardening are founded upon experience of similar effects; and it is well known that cuttings of plants succeed best in a border with a northern aspect protected from the wind; or, if otherwise situated, they require to be screened from the force of a noon-day sun. If these precautions be unattended to, they speedily droop and die. For the same reason, the autumn is selected for placing them in the ground, as well as for transplanting trees; the atmosphere at that season being saturated with moisture, is not found to exhaust the plant before it has become rooted in the soil.

Over the absolute state of vapour in the air we are wholly powerless, and by no system of watering can we affect the dew-point in the free atmosphere. This is determined in the upper regions: it is only,

therefore, by these indirect methods, and by the selection of proper seasons, that we can preserve the more tender shoots of the vegetable kingdom from the injurious effects of excessive exhalation.

Radiation, the second cause which I have mentioned as producing a sudden and injurious influence upon the tender products of the garden, is one that has been little understood, till of late years, by the natural philosopher; and even to this day has not been rendered familiar to the practical gardener; who, although he has been taught by experience to guard against some of its effects, is totally unacquainted with the theory of his practice. Dr. Wells, to whose admirable *Essay upon Dew* we are so much indebted for our present knowledge upon this important subject, thus candidly remarks upon this anticipation of science: "I had often, in the pride of half-knowledge, smiled at the means frequently employed by gardeners to protect tender plants from cold; as it appeared to me impossible that a thin mat or any such flimsy substance could prevent them from attaining the temperature of the atmosphere, by which alone I thought them liable to be injured. But when I had learned that bodies on the surface of the earth become, during a still and serene night, colder than the atmosphere, by radiating their heat to the heavens, I perceived immediately a just reason for the practice which I had before deemed useless."

The power of emitting heat in straight lines in every direction, independently of contact, may be regarded as a property common to all matter; but

differing in degree in different kinds of matter. Co-existing with it, in the same degrees, may be regarded the power of absorbing heat so emitted from other bodies. Polished metals, and the fibres of vegetables, may be considered as placed at the two extremities of the scale upon which these properties in different substances may be measured. If a body be so situated that it may receive just as much radiant heat as itself projects, its temperature remains the same; if the surrounding bodies emit heat of greater intensity than the same body, its temperature rises, till the quantity which it receives exactly balances its expenditure; at which point it again becomes stationary: and if the power of radiation be exerted under circumstances which prevent a return, the temperature of the body declines. Thus, if a thermometer be placed in the focus of a concave metallic mirror, and turned towards any clear portion of the sky, at any period of the day, it will fall many degrees below the temperature of another thermometer placed near it, out of the mirror: the power of radiation is exerted in both thermometers, but to the first all return of radiant heat is cut off, while the other receives as much from the surrounding bodies as itself projects. This interchange amongst bodies takes place in transparent *media* as well as in *vacuo;* but in the former case the effect is modified by the equalizing power of the medium.

Any portion of the surface of the globe which is fully turned towards the sun receives more radiant heat than it projects, and becomes heated; but when, by the revolution of the axis, this portion is turned

from the source of heat, the radiation into space still continues, and being uncompensated, the temperature declines. In consequence of the different degrees in which different bodies possess this power of radiation, two contiguous portions of the system of the earth will become of different temperatures; and if on a clear night we place a thermometer upon a glass-plat, and another upon a gravel-walk or the bare soil, we shall find the temperature of the former many degrees below that of the latter; the fibrous texture of the grass is favourable to the emission of the heat, but the dense surfaces of the gravel seem to retain and fix it. But this unequal effect will only be perceived when the atmosphere is unclouded, and a free passage is open into space; for even a light mist will arrest the radiant matter in its course, and return as much to the radiating body as it emits. The intervention of more substantial obstacles will of course equally prevent the result, and the balance of temperature will not be disturbed in any substance which is not placed in the clear aspect of the sky. A portion of a grass-plat under the protection of a tree or hedge, will generally be found, on a clear night, to be 8° or 10° warmer than surrounding unsheltered parts, and it is well known to gardeners that less dew and frost are to be found in such situations than in those which are wholly exposed.

There are many independent circumstances which modify the effects of this action, such as the state of the radiating body, its power of conducting heat, &c. If, for instance, the body be in a liquid or aëriform

state, although the process may go on freely, as in water, the cold produced by it will not accumulate upon the surface, but will be dispersed by known laws throughout the mass; and if a solid body be a good radiator but a bad conductor of heat, the frigorific effect will be condensed upon the face which is exposed. So, upon the surface of the earth, absolute stillness of the atmosphere is necessary for the accumulation of cold upon the radiating body; for if the air be in motion, it disperses and equalizes the effect, with a rapidity proportioned to its velocity.

It is upon these principles that Dr. Wells has satisfactorily explained all the phenomena connected with dew and hoar frost. This deposition of moisture is owing to the cold produced in bodies by radiation, which condenses the atmospheric vapour upon their surfaces. It takes place upon vegetables, but not upon the naked soil. The fibres of short grass are particularly favourable to its formation. It is not produced either in cloudy or in windy weather, or in situations which are not perfectly open to the sky. It is never formed upon the good conducting surfaces of metals, but is rapidly deposited upon the badly conducting surfaces of filamentous bodies, such as cotton, wool, &c.

In remarking that dew is never formed upon metals, it is necessary to distinguish a secondary effect, which often causes a deposition of moisture upon every kind of surface indiscriminately. The cold which is produced upon the surface of the radiating body, is communicated by slow degrees to the surrounding atmo-

sphere; and, if the effect be great and of sufficient continuance, moisture is not only deposited upon the solid body, but is precipitated in the air itself; from which it slowly subsides, and settles upon everything within its range.

The formation of dew is one of the circumstances which modify and check the refrigerating effect of radiation; for, as the vapour is condensed, it gives out the latent heat with which it was combined in its elastic form, and thus, no doubt, prevents an excess of depression which might in many cases prove injurious to vegetation. A compensating arrangement is thus established, which, while it produces all the advantages of this gentle effusion of moisture, guards against the injurious concentration of the cause by which it is produced.

The effects of radiation come under the consideration of the horticulturist in two points of view: the first regards the primary influence upon vegetables exposed to it; the second the modifications produced by it upon the atmosphere of particular situations. To vegetables growing in the climates for which they were originally designed by nature, there can be no doubt that the action of radiation is particularly beneficial, from the deposition of moisture which it determines upon their foliage: but to tender plants artificially trained to resist the rigours of an unnatural situation, this extra degree of cold may prove highly prejudicial. It also appears probable, from observation, that the intensity of this action increases with the distance from the equator to the poles; as the lowest depression

of the thermometer which has been registered between the tropics, from this cause, is 12°, whereas in the latitude of London, it not unfrequently amounts to 17°. But, however this may be, it is certain that vegetaiion in this country is liable to be affected at night from the influence of radiation, by a temperature below the freezing point of water, ten months in the year; and even in the two months, July and August, which are the only exceptions, a thermometer covered with wool will sometimes fall to 35°. It is, however, only low vegetation upon the ground which is exposed to the full rigour of this effect. In such a situation the air which is cooled by the process, lies upon the surface of the plants, and from its weight cannot make its escape; but from the foliage of a tree or shrub, it glides off and settles upon the ground.

Anything which obstructs the free aspect of the sky arrests, in proportion, the progress of this refrigeration, and the slightest covering of cloth or matting annihilates it altogether. Trees trained upon a wall or paling, or plants sown under their protection, are at once cut off from a large portion of this evil; and are still further protected, if within a moderate distance of another opposing screen. The most perfect combination for the growth of exotic fruits in the open air would be a number of parallel walls within a short distance of one another, facing the south-east quarter of the heavens: the spaces between each should be gravelled, except a narrow border on each side, which should be kept free from weeds and other short vegetables. On the southern sides of these walls, peaches,

nectarines, figs, &c., might be trained to advantage, and on their northern sides many hardier kinds of fruit would be very advantageously situated. Tender exotic trees would thus derive all the benefit of the early morning sun, which would at the earliest moment dissipate the greatest accumulation of cold which immediately precedes its rise, and the injurious influence of nocturnal radiation would be almost entirely prevented. Upon trees so trained, the absolute perpendicular impression could have little effect, and this little might even be prevented by a moderate coping.

Mats or canvass, upon rollers to draw down occasionally in front of the trees, at the distance of a foot or two from their foliage, would, I have no doubt, be a great advantage in certain dry states of the atmosphere, before alluded to, and in the case of walls which are not opposed to others, would be a good substitute for the protection of the latter.

Experience has taught gardeners the advantages of warding off the effects of frost from tender vegetables, by loose straw or other litter, but the system of matting does not appear to be carried to that extent which its simplicity and efficacy would suggest. Neither does the manner of fixing the screen exhibit a proper acquaintance with the principle upon which it is resorted to: it is generally bound tight round the tree which it is required to protect, or nailed in close contact with its foliage.

Now it should be borne in mind that the radiation is only transferred from the tree to the mat, and the cold of the latter will be conducted to the former in

every point where it touches. Contact should therefore be prevented by hoops or other means properly applied, and the stratum of air which is enclosed will, by its low conducting power, effectually secure the plant. With their foliage thus protected, and their roots well covered with litter, many evergreens might doubtless be brought to survive the rigour of our winters, which are now confined to the stunted growth of the greenhouse and conservatory.

The secondary effect which radiation has upon the climate of particular situations, is a point which is less frequently considered than the primary one which we have been investigating; but which requires, perhaps, still more attention. The utmost concentration of cold can only take place in a perfectly still atmosphere: a very slight motion of the air is sufficient to disperse it. A low mist is often formed in meadows in particular situations, which is the consequence of the slow extension of this cold in the air, as before described: the agitation of merely walking through this condensation is frequently sufficient to disperse and melt it. A valley surrounded by low hills is more liable to the effects of radiation than the tops and sides of the hills themselves: and it is a well-known fact that dew and hoar frost are always more abundant in the former than in the latter situations. It is not meant to include in this observation, places surrounded by lofty and precipitous hills which obstruct the aspect of the sky, for in such, the contrary effect would be produced. Gentle slopes, which break the undulations of the air, without naturally circumscribing the heavens, are more efficient

in promoting this action; and it is worthy of remark and consideration, that by walls and other fences we may artificially combine circumstances which may produce the same injurious effect.

But the influence of hills upon the nightly temperature of the valleys which they surround, is not confined to this insulation; radiation goes on upon their declivities, and the air which is condensed by the cold rolls down and lodges at their feet.

Their sides are thus protected from the chill, and a double portion falls upon, what many are apt to consider, the more sheltered situation. Experience amply confirms these theoretical considerations. It is a very old remark, that the injurious effects of cold occur chiefly in hollow places, and that frosts are less severe upon hills than in neighbouring plains. It is consistent with my own observations that the leaves of the vine, the walnut-tree, and the succulent shoots of dahlias and potatoes, are often destroyed by frost in sheltered valleys, on nights when they are perfectly untouched upon the surrounding eminences; and I have seen a difference of 30° on the same night between two thermometers placed in the two situations, in favour of the latter.

The advantages of placing a garden upon a gentle slope must be hence very apparent: a running stream at its foot, would secure the further benefit of a contiguous surface, not liable to refrigeration, and would prevent any injurious stagnation of the air. Few situations are likely to fulfil all the conditions which theory would suggest for the most perfect mitigation of

the climate in the open air; but the preceding remarks may not be without their use in pointing out localities which, with this view, are most to be avoided.

Little is in the power of the horticulturist to effect in the way of exalting the powers of the climate in the open air; except by choice of situation with regard to the sun, and the concentration of its rays upon walls and other screens. The natural reverberation from these and the subjacent soil, is however very effective, and few of the productions of the tropical regions are exposed to a greater heat than a well-trained tree upon a wall in summer. Indeed, it would appear from experiment, that the power of radiation from the sun, like that of radiation from the earth, increases with the distance from the equator; and there is a greater difference between a thermometer placed in the shade, and another in the solar rays, in this country, than in Sierra Leone or Jamaica. The observation of the President of this Society upon the growth of pine-apples is in exact accordance with this idea; for he has remarked that this species of plant, though extremely patient of a high temperature, is not by any means so patient of the action of very continued bright light as many other plants, and much less so than the fig and orange-tree; and he is inclined to think that on this account they may be found to ripen their fruit better in the spring than in the middle of the summer*. This energy of the sun is at times so great that it often becomes necessary to shade delicate

* See *Horticultural Transactions*, vol. iv. p. 548.

flowers from its influence; and I have already pointed out a case in which it would be desirable to try the same precaution with the early blossom of certain fruit-trees. The greatest power is put forth in this country in June, while the greatest temperature of the air does not take place till July. The temperature of summer may thus be anticipated a month, in well-secured situations.

The greatest disadvantage to which horticulture is subject in this climate, is the uncertainty of clear weather; a circumstance which art has, of course, no means to control; no artificial warmth is capable of supplying the deficiency when it occurs; and without the solar beams fruits lose their flavour and flowers the brightness of their tints. It has been attempted to communicate warmth to walls by means of fire and flues, but without the assistance of glass no great success has attended the trial.

It is well known that solar heat is absorbed by different substances with various degrees of facility dependent upon their colours, and that black is the most efficacious in this respect. It has therefore been proposed to paint garden walls of this colour; but no great benefit is likely to arise from this suggestion. It is probable that in the spring, when the trees are devoid of foliage, the wood may thus be forced to throw out its blossom somewhat earlier than it otherwise would; but this would be rather a disadvantage, as the flower would become exposed to the vicissitudes of an early spring. It is more desirable to check than to force this delicate and important process of vegetation, as

much injury may arise from its premature development. When the tree has put forth its foliage, the colour of its protecting support can have no influence in any way: the leaves cover the surface, and absorb the rays by their own inherent powers. The only known advantage which can be taken of this peculiar power in dark substances, is in the case of covering up fruits, to preserve them from the ravages of flies; grapes which are inclosed in bags of black crape ripen better than those in white; but I believe that it is admitted that neither do so well as those which are freely exposed.

I come now to the consideration of a confined atmosphere; the management of which being entirely dependent upon art, requires in the horticulturist a more extended acquaintance with the laws of nature with regard to climate, and greater skill and experience in the application of his means. The plants which require this protection are in the most artificial state which it is possible to conceive; for, not only are their stems and foliage subject to the vicissitudes of the air in which they are immersed, but, in most cases, their roots also. The soil in which they are set to vegetate is generally contained in porous pots of earthenware, to the interior surface of which the tender fibres quickly penetrate and spread in every direction; they are thus exposed to every change of temperature and humidity, and are liable to great chills from any sudden increase of evaporation. This part of the subject naturally divides itself into two branches. The first regards the

treatment of such exotics as are wholly dependent upon the artificial atmosphere of hot-houses: the second refers to the management of those hardier plants which only require to be preserved in green-houses part of the year, but during the summer months are exposed to the changes of the open air. I shall offer a few remarks first on the atmosphere of a hot-house.

The principal considerations which generally guide the management of gardeners in this delicate department are those of temperature; but there are others, regarding moisture, which are, I conceive, of at least equal importance. The inhabitants of the hot-house are all natives of the torrid zone, and the climate of this region is not only distinguished by an unvarying high degree of heat, but also by a very vaporous atmosphere. Colonel Sabine, in his meteorological researches between the tropics, rarely found, at the hottest period of the day, so great a difference as 10° between the temperature of the air and the dew-point; making the degree of saturation about 730, but most frequently 5° or 850; and the mean saturation of the air could not have been below 910. Now, I believe, that if the hygrometer were consulted, it would be no uncommon thing to find in hot-houses, as at present managed, a difference of 20° between the point of condensation and the air, or a degree of moisture falling short of 500. The danger of over-watering most of the plants, especially at particular periods of their growth, is in general very justly appreciated; and in consequence the earth at their roots is kept in a state

comparatively dry; the only supply of moisture being commonly derived from the pots, the exhalations of the leaves is not enough to saturate the air, and the consequence is a prodigious power of evaporation. This is injurious to the plants in two ways: in the first place, if the pots be at all moist, and not protected by tan or other litter, it produces a considerable degree of cold upon their surface, and communicates a chill to the tender fibres with which they are lined. The danger of such a chill is carefully guarded against in the case of watering, for it is one of the commonest precautions not to use any water of a temperature at all inferior to that of the hot air of the house; inattention to this point is quickly followed by disastrous consequences. The danger is quite as great from a moist flower-pot placed in a very dry atmosphere.

The custom of lowering the temperature of fluids in hot climates, by placing them in coolers of wet porous earthenware, is well known, and the common garden-pot is as good a cooler for this purpose as can be made. Under the common circumstances of the atmosphere of a hot-house, a depression of temperature amounting to 15° or 20°, may easily be produced upon such an evaporating surface. But the greatest mischief will arise from the increased exhalations of the plants so circumstanced, and the consequent exhaustion of the powers of vegetation. The flowers of the torrid zone are many of them of a very succulent nature, largely supplied with cuticular pores, and their tender buds are unprovided with those integuments and other wonderful provisions by which nature guards

her first embryo productions in more uncertain climates. Comparatively speaking, they shoot naked into the world, and are suited only to that enchanting mildness of the atmosphere, for which the whole system of their organization is adapted. In the tropical climates the sap never ceases to flow, and sudden checks or accelerations of its progress are as injurious to its healthy functions as they are necessary in the plants of more variable climates to the formation of those *hybernacula* which are provided for the preservation of the shoots in the winter season. Some idea may be formed of the prodigiously increased drain upon the functions of a plant arising from an increase of dryness in the air from the following consideration. If we suppose the amount of its perspiration, in a given time, to be 57 grains, the temperature of the air being 75°, and the dew-point 70°, or the saturation of the air being 849, the amount would be increased to 120 grains in the same time if the dew-point were to remain stationary, and the temperature were to rise to 80°; or in other words, if the saturation of the air were to fall to 726.

Besides this power of transpiration, the leaves of vegetables exercise also an absorbent function, which must be no less disarranged by any deficiency of moisture. Some plants derive the greatest portion of their nutriment from the vaporous atmosphere, and all are more or less dependent upon the same source. The *Nepenthes distillatoria* lays up a store of water in the cup formed at the end of its leaves, which is probably secreted from the air, and applied to the exigencies of the plant when exposed to drought, and the quantity,

which is known to vary in the hot-house, is no doubt connected with the state of moisture of the atmosphere.

These considerations must be sufficient, I imagine, to place in a strong light the necessity of a strict attention to the atmosphere of vapour in our artificial climates, and to enforce as absolute an imitation as possible of the example of nature. The means of effecting this, is the next object of our inquiry.

Tropical plants require to be watered at the root with great caution, and it is impossible that a sufficient supply of vapour can be kept up from this source alone. There can, however, be no difficulty in keeping the floor of the house, and the flues, continually wet, and an atmosphere of great elasticity may thus be maintained in a way perfectly analogous to the natural process. Where steam is employed as the means of communicating heat, an occasional injection of it into the air may also be had recourse to: but this method would require much attention on the part of the superintendent, whereas the first cannot easily be carried to excess.

It is true that damp air or floating moisture of long continuance would also be detrimental to the health of the plants, for it is absolutely necessary that the process of transpiration should proceed; but there is no danger that the high temperature of the hot-house should ever attain the point of saturation by spontaneous evaporation. The temperature of the external air will always keep down the force of the vapour; for as in the natural atmosphere the dew-point at the surface of the earth is regulated by the

cold of the upper regions, so in a house the point of deposition is governed by the temperature of the glass with which it is in contact. In a well-ventilated hot-house, by watering the floor in summer, we may bring the dew-point within 4° or 5° of the temperature of the air, and the glass will be perfectly free from moisture; by closing the ventilators we shall probably raise the heat 10° or 15°, but the degree of saturation will remain nearly the same, and a copious dew will quickly form upon the glass, and will shortly run down in streams. A process of distillation is thus established, which prevents the vapour from attaining the full elasticity of the temperature.

This action is beneficial within certain limits, and at particular seasons of the year; but when the external air is very cold, or radiation proceeds very rapidly, it may become excessive and prejudicial. It is a well-known fact, but one which I believe has never yet been properly explained, that by attempting to keep up in a hot-house the same degree of heat at night as during the day, the plants become scorched; from what has been premised, it will be evident that this is owing to the low temperature of the glass, and the consequent low dew-point in the house, which occasions a degree of dryness which quickly exhausts the juices.

Much of this evil might be prevented by such simple and cheap means as an external covering of mats or canvass.

The heat of the glass of a hot-house at night does not probably exceed the mean of the external and internal air, and taking these at 80° and 40°, 20° of

dryness are kept up in the interior; or a degree of saturation not exceeding 528. To this, in a clear night, we may add at least 6° for the effects of radiation, to which the glass is particularly exposed, which would reduce the saturation to 434, and this is a degree of drought which must be nearly destructive. It will be allowed that the case which I have selected is by no means extreme, and it is one which is liable to occur even in the summer months. Now, by an external covering of mats, &c., the effects of radiation would be at once annihilated, and a thin stratum of air would be kept in contact with the glass which would become warmed, and consequently tend to prevent the dissipation of the heat. But no means would of course be so effective as double glass including a stratum of air: indeed, such a precaution in winter seems almost essential to any great degree of perfection in this branch of horticulture. When it is considered that a temperature at night of 20° is no very unfrequent occurrence in this country, the saturation of the air may upon such occasions fall to 120, and such an evil can only at present be guarded against by diminishing the interior heat in proportion.*

* During my stay at Berlin, I was informed that one of the hot-houses of the Botanical Garden in the neighbourhood of that city was constructed with double glass. I was prevented by several unforeseen disappointments from seeing the construction, and making such inquiries as might have explained the steps by which experience had been led to the adoption of means which I, being totally unaware of the fact, had recommended from theoretical considerations alone. Upon my return, I found that the existence of such houses was totally unknown in this country, and Dr. Lindley

By materially lowering the temperature we communicate a check which is totally inconsistent with the welfare of tropical vegetation. The chill which is instantaneously communicated to the glass by a fall of

kindly undertook to ascertain all the particulars from the correspondents of the Horticultural Society. The following is an extract of a letter from Mr. Otto, which he received, in answer to his inquiries:—

"*17th March*, 1827.

"In the year 1804 a hot-house with double windows was erected in the Botanic Garden at Berlin, which completely answered the purpose expected from it. Since that time most of the hot-houses have been built in a similar way, and provided with double windows. The main objects in the application of these windows are the following, viz.: to save the very laborious task of covering and uncovering the windows during rainy or cold weather, by means of wooden shutters or mats; to admit, uninterruptedly, the light to the plants—which cannot be the case if the windows are covered; protection against cold and wet, whereby the dropping of rain or snowy weather is totally avoided. These would be the chief advantages of houses with double windows. On the other hand, it cannot be denied, that a great deal of the sun's light and warmth is withheld from the plants by the obstruction of the sun's rays; and on this account the double windows are applied only to larger houses, in which stout and full-grown plants are cultivated. In smaller ones, where young plants only are kept, as also in forcing-houses for fruit, &c., I do not find them equally applicable, because much light and warmth of the sun is lost by them. We generally put on the double windows here in September, on the tropical houses; but on the conservatories, later in November. Those standing in the front are generally put on later, and again removed earlier, which is entirely regulated by the state of the weather. The tropical, as well as all New Holland and Cape plants, keep extremely well in these houses, and I shall probably never follow any other method. Even the snow never lies long on the upper windows, but melts and runs down on them."

rain and snow, and the consequent evaporation from its surface, must also precipitate the internal vapour, and dry the included air to a very considerable amount, and the effect should be closely watched. I do not conceive that the diminution of light which would be occasioned by the double panes, would be sufficient to occasion any serious objection to the plan. The difference would not probably amount to as much as that between hot-houses with wooden rafters and lights, and those constructed with curvilinear iron bars, two of which have been erected in the garden of the Horticultural Society. It might also possibly occasion a greater expansion of the foliage; for it is known that in houses with a northern aspect, the leaves grow to a larger size than in houses which front the south. Nature thus makes an effort to counteract the deficiency of light by increasing the surface upon which it is destined to act.

The present method of ventilating hot-hou also objectionable, upon the same principles which have been endeavouring to explain. A communication is at once opened with the external air, while the hot and vaporous atmosphere is allowed to escape at the roof; the consequence is, that the dry external air rushes in with considerable velocity, and becoming heated in its course, rapidly abstracts the moisture from the pots and foliage. This is the more dangerous, inasmuch as it acts with a rapidity proportioned in a very high degree to its motion. I would suggest, as a matter of easy experiment, whether great benefit might not arise from warming the air to a

certain extent, and making it traverse a wet surface before it is allowed to enter the house.

There is one practice universally adopted by gardeners, which is confirmatory of these theoretical speculations, namely, that of planting tender cuttings of plants in a hot-bed, and covering them with a double glass. Experience has shown them that many kinds will not succeed under any other treatment. The end of this is obviously to preserve a saturated atmosphere; and it affords a parallel case to that of Dr. Wells, of the anticipation of theory by practice.

The effect of keeping the floor of the hot-house continually wet has been already tried at the Society's garden, at my suggestion, and it has been found that the plants have grown with unprecedented vigour: indeed their luxuriance must strike the most superficial observer.

To the human feelings the impression of an atmosphere so saturated with moisture is very different from one heated to the same degree without this precaution; and any one coming out of a house heated in the common way, into one well charged with vapour, cannot fail to be struck with the difference. Those who are used to hot climates have declared that the feel and smell of the latter exactly assimilate to those of the tropical regions.

But there is a danger attending the very success of this experiment, which cannot be too carefully guarded against. The trial has been made in the summer months when the temperature of the external air has not been low, nor the change from day to night very

great. In proportion to the luxuriance of the vegetation, will be the danger of any sudden check; and it is much to be feared, that, unless proper precautions are adopted, the cold, long nights of winter may produce irreparable mischief.

I am aware that a great objection attaches to my plan of the double glass, on account of the expense; but I think that this may appear greater at first sight than it may afterwards be found to be in practice. It is however, at all events, I submit, a point worthy of the Horticultural Society to determine; and if the suggestion should be found to be effective, the lights of many frames, which are not commonly in use in winter, might, without much trouble, be fitted to slide over the hot-houses during the severe season; and in the spring, when they are wanted for other purposes, their places might be supplied at night by mats or canvass.

The principles which I have been endeavouring to illustrate should be doubtless extended to the pinery and the melon-frame, in the latter of which a saturated atmosphere might be maintained by shallow pans of water. An increase in the size of the fruit might be anticipated from this treatment, without that loss of flavour which would attend the communication of water to the roots of the plants.

I have but few additional observations to offer upon the artificial climate of a green-house. The remarks which have been made upon the atmosphere of the hot-house are applicable to it, though not to the same extent. The plants which are subject to this

culture seldom require an artificial temperature greater than 45° or 50°, and few of them would receive injury from a temperature so low as 35°. When in the house they are effectually sheltered from the effects of direct radiation, which cannot take place through glass: but the glass itself radiates very freely, and thus communicates a chill to the air, which might effectually be prevented by rolling mats. With this precaution, fire would be but rarely wanted in a good situation, to communicate warmth. But in this damp climate it may be required to dissipate moisture. The state of the air should be as carefully watched with this view, as where a high temperature is necessary, to guard against the contrary extreme. Free transpiration, as I have before remarked, is necessary to the healthy progress of vegetation, and when any mouldiness or damp appears upon the plants, the temperature of the air should be moderately raised, and free ventilation allowed. When the pots in the proper season are moved into the open air, it would contribute greatly to their health and preserve them from the effects of too great evaporation, to imbed them well in moss or litter: as a substitute for this precaution, the plants are generally exposed to a northern or eastern aspect, where the influence of the sun but rarely reaches them, but which would be very beneficial if their roots were properly protected. The advantage of such a protection may be seen when the pots are plunged into the soil, a method which communicates the greatest luxuriance to the plants, but unfits them to resume their winter stations.

When a green-house is made use of, as it often is, after the removal of the pots, to force the vine, the same precautions should be attended to as in the management of the hot-house, and the elasticity of the vapour should be maintained by wetting the floor; but after a certain period a great degree of dryness should be allowed to prevail, to enable the tree to ripen its wood, and form the winter protection for its buds. In this its treatment differs from that of the tropical plants, which require no such change, and to which, on the contrary, it would be highly detrimental. The same observation applies to forcing-houses for peaches, and other similar kinds of trees. As soon as the fruit is all matured they should be freely exposed to the changes of the weather.

Upon an attentive consideration and review of the subject, it appears to me certain that a frequent consultation of the indications of the hygrometer is quite as necessary to the horticulturist as of those of the thermometer; and it is not unworthy of the consideration of the Horticultural Society whether correct registers of the state of the climate, both in their houses and out of doors, and a connected series of experiments upon the modifications of which it is susceptible, might not contribute something to the perfection of that art, which they are making such honourable exertions to perfect and communicate.

To me it will be a source of great satisfaction if any observations which I have made, or may make, upon the subject of climate, should prove at all instrumental in forwarding their important views.

[The following remarks, extracted from an article by Professor Lindley, in the *Gardeners' Chronicle*, of March 1, 1845, published only a fortnight before the death of Professor Daniell, will show the great practical value of the suggestions contained in the preceding Essay:—

"It is the good management of the atmosphere of glass-houses that has, more than any other thing, changed the aspect of the plants within them. It is to the careful and diligent application, by clever practical men, of the principles explained in the year 1824 by Professor Daniell, that we mainly owe our superiority to our predecessors. At the time when that important document was printed there was not one gardener in a hundred who remembered that the atmosphere contained any water at all; not one in a thousand who was aware that the quantity floating in it could be actually measured, and read off, like temperature by a thermometer scale; not one in ten thousand who considered that the healthiness of a plant depended essentially upon the relative amounts of atmospheric moisture, light, and temperature, and the peculiar condition of the plant exposed to them. If plants were flagging, the roots were watered; if some very particular cause appeared to call for it they were syringed, and that was all. We are old enough to remember the surprise that was felt at the results obtained when the practice of steaming plants was first resorted to. The opinion then was that it was the *warmth* of the vapour that produced so beneficial an effect.

"But Mr. Daniell taught the gardening world that the amount of moisture permanently surrounding plants is of the very first importance. He showed them the folly of hoping to keep in health a tropical vegetation naturally accustomed to an atmosphere almost saturated with moisture, by surrounding it with air not holding in suspension half that amount of water. He pointed out the impossibility of obtaining a command of atmospheric moisture by watering the roots; he showed, by the unquestionable evidence of the hygrometer, that what was in those days called a moist air was in

truth a very dry one; that our feelings are not to be depended upon in such a matter; and that hygrometrical instruments alone could determine whether the climate provided for plants was suitable or unsuitable to the plants exposed to it.

"In those days, when the hygrometer was first brought into use, what was called a damp atmosphere was frequently seen to indicate a degree of moisture falling short of 500, saturation being represented by 1000; and it was found that 120 was not uncommon—a state of things sufficient to impair the vitality of the most vigorous vegetation. These important statements brought into use the practice of abstaining from root-watering and the deluging of pathways, walls, and other evaporating surfaces. To this succeeded evaporating pans; and lastly, the tank system has been brought into action: each step being in advance of its predecessor.

"Besides the circumstances now mentioned, a number of minor questions were discussed by Mr. Daniell in the paper already referred to. Gardeners of quick apprehension immediately began to act in accordance with the philosophical views therein enunciated; the more ignorant and dull-witted copied them; and thus, by degrees, with the aid of twenty years' experimenting, the English art of managing artificial climate has been established. For that we are indebted to Mr. Daniell; and we strongly advise all who have the means, to study his paper with much diligence. They will still find it a store-house of valuable facts and still more valuable suggestions, one of which, as yet but little acted on, we shall take an early opportunity of pressing upon public consideration."]

REMARKS

UPON THE BAROMETER AND THERMOMETER,

AND THE

MODE OF USING METEOROLOGICAL INSTRUMENTS IN GENERAL.

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[*Reprinted from the Second Edition.*]

By offering the following remarks upon meteorological instruments, I would not wish it to be supposed that I claim, for the observations which I have hitherto recorded, a greater degree of precision than attention to the usual precautions has been sufficient to confer: but in the course of my experiments, the necessity of much greater care and method has become strongly impressed upon my mind, and I think that it may not be wholly without its use, to indicate some measures which the result of my experience suggests, as likely to ensure that degree of perfection, of which the science of meteorology is doubtless susceptible. I have little of novelty to offer upon the subject; but if, by repeating well-known observations, I can contribute to excite that attention to them which is absolutely necessary to success; if the numerous observers of atmospheric phenomena may possibly be thus engaged to that strict co-operation, which alone can prevent their daily labours from proving abortive, a great and important object will be attained.

Much of my attention has lately been given to the manufacture of barometers. The Committee of the

Royal Society, appointed to take into consideration the state of the meteorological instruments, did me the honour to request that I would attend to the construction of a new barometer for their apartments; and as, in the course of the close attention which I paid to the most minute details, I had occasion to make many practical remarks, I cannot, I think, do better than here introduce the account of the process which I had prepared for the Society.

In the course of the experiments I was led to a new method of filling the tube, which I flatter myself may prove generally useful, and tend, by the facilities which it affords, to the perfection of the instrument.

Previous to commencing the operation, some experiments were undertaken to ascertain the practicability and effect of introducing the metal, after the air had been abstracted, as nearly as possible, by means of an air-pump, and the mercury and interior surface had been exposed to the desiccating influence of a large surface of sulphuric acid. For this purpose a barometer tube was fitted with a stop-cock, which was screwed into the under surface of a pump-plate; on the upper surface stood a glass dish, perforated in the centre, and containing the acid. In this was placed a stand with glass legs, which received a funnel, the stem of which being drawn out into a capillary tube, passed down into the mouth of a small paper cone, resting upon the tube. The aperture at the upper part of the stem was closed by an iron plug, ground to fit, between which and the capillary opening was placed some cotton. The glass funnel was filled with clean mercury, care-

fully boiled, and many times filtered, and the whole was covered with a glass receiver. Through a collar of leather, in the upper part of the receiver, passed an iron rod, which moved freely up and down, and fitted into a screw in the plug before mentioned, by which means it could be drawn up and replaced, at pleasure. The apparatus being thus arranged, the pump was worked, and the air exhausted from the receiver and tube. Air was at first given off from the surface of the acid in abundance, and a few bubbles passed up from between the mercury and the glass; but none appeared upon the surface of the mercury. When the rarefaction had been carried as far as possible, the siphon-gauge stood at about half an inch. The iron plug was carefully withdrawn, and the mercury began to trickle very gradually into the tube. In its fall it was broken into small globules, many of which adhered to the sides of the glass; and, notwithstanding the utmost precaution and frequent repetitions of the experiment, the column of mercury, as it rose, contained very minute cavities, which decreased in size as the weight increased; and when the pressure of the atmosphere was restored, were only discernible upon very close examination. When the air was again extracted, they returned to their former size, and again diminished upon its restoration. The difficulty of getting rid of these cavities appears to me to arise chiefly from their form; for the mercury, assuming the shape and properties of a dome round the bubble, resists a degree of pressure which would otherwise cause it to run together.

To avoid this mechanical action of the fall of the mercury, the apparatus was varied as follows:—A small tube was passed down to the bottom of the barometer-tube, and was fastened at the top by a piece of cork, to prevent its coming in contact with the sides. The lower aperture had been lessened, and the small paper funnel was inserted into the upper end. The exhaustion having been made as before, the mercury was allowed to trickle down the interior of the inner small tube, from the bottom of which it issued slowly; and gradually rose in the larger, in perfect and uninterrupted contact with the glass. When the tube was full, the air was let into the receiver, and the tube detached from the plate. To prevent the possibility of the disengagement of any particles of air, which might be entangled in the mercury of the small tube, its orifice was hermetically sealed by a lamp, and the tube itself full of mercury, carefully withdrawn from the large one. The closest examination, with a microscope, of the barometer-tube so filled, failed to detect the minutest air-bubble, and the surface everywhere was as resplendent as that of the most perfect mirror. The application of heat produced no alteration in this appearance, nor any traces of either air or moisture. The small tube, upon inspection, was found to contain very minute and scarcely visible specks, like those of the tubes filled in the first method; but these were, of course, diminished in quantity, in proportion to the diminution of the tube in which they were formed.

The success of this experiment was so great, that,

in any common case, it would scarcely have been thought necessary to subject the barometer to the troublesome and hazardous process of boiling the mercury; but upon this occasion it was resolved that no possible precaution should be omitted.

The tube which was selected for the Society's barometer is $33\frac{3}{4}$ inches long, its exterior diameter 0·86 inch, and the diameter of its bore 0·530 inch.

These measures were taken at the upper extremity, and it is very regular for 14 inches, but enlarges a little from that point downwards. It is ground flat at the lower end.

Many tubes were destroyed, after all the trouble bestowed upon their mensuration and filling, by the after-process of boiling, which, in tubes of such large capacity, was found to be very troublesome and hazardous, and required the glass to be of a red-heat. The above dimensions are those of the barometer now complete.

The cistern is turned in well-seasoned mahogany, and there is a small cavity in its bottom to receive the end of the tube, which rests upon it: a groove communicates with the cavity, to ensure the free passage of the mercury. By means of the float in front, the level may be very accurately taken. Fifty inches, measured in the upper part of the tube before it was sealed, in four equal proportions, raised the float exactly half an inch; the correction, therefore, for the capacity of the cistern, is $\frac{1}{100}$th.

The cistern being accurately levelled, and the tube and thermometer both in their places, the quantity of

mercury was adjusted to the upper edge of the black line on the stem of the float: a card gauge of nearly the diameter of the cistern was then fitted to slide upon the tube, which was fixed perpendicularly in its place. The lower edge of the gauge was made to coincide with the surface of the mercury on both sides, and at its contact with the glass, two distinct marks were scratched upon the tube. From these marks, twenty-nine inches were measured off by a brass dividing engine, which was formerly the property of the late Mr. Cavendish, and at that distance another distinct mark was made. The utmost care was taken to read off these distances by means of lenses, and the temperature of the scale, the glass, and the mercury, was 54°.

It being deemed too hazardous an experiment to attempt to boil, at once, so large a body of mercury as would be contained in a tube of this capacity, it was resolved to perform the operation in two portions, and under the diminished pressure produced by an air-pump. Accordingly, seventeen inches of mercury were introduced into the tube with all the precautions above described. During the exhaustion, no air was disengaged from the mercury, care having been taken to fill the funnel without agitation. The contact with the glass, while the siphon gauge of the pump stood at ·4 in., was perfect, and the appearance of the tube when detached as bright and compact as could be wished. The air was again exhausted, and by means of a stop-cock, the vacuum preserved. The tube was then gradually heated before a fire, and the boiling, afterwards, cautiously begun over a large spirit-lamp.

The upper part of the column was first strongly heated, and when it had arrived at the point of ebullition, the boiling was slowly continued downwards. When it had reached the bottom, it was again as gradually conducted to the top. The bubbles of vapour freely passed, with the assistance of a slight degree of agitation, from one end of the column to the other; and very bright flashes of green light accompanied their extrication. One minute globule of air alone was detected during the heating, notwithstanding the diminished pressure, and this was readily extricated; and there was not the slightest condensation of moisture visible in the cold portion of the tube.

The cooling was conducted with all the precautions used in heating; and to allow the mercury to resume the temperature of the air, the completion of the process was deferred till the next day. After fifteen hours' repose, upon opening the stop-cock, the exhaustion was found to have been perfectly maintained: the apparatus was again arranged, the small tube being made just to touch the surface of the mercury in the larger. A quantity of mercury was then introduced as before, which was found after the interior tube had been withdrawn, to amount to twelve inches and a half. The appearance was as perfect as in the first operation, except that two or three very minute specks appeared at the junction of the two portions. These scarcely-visible air-bubbles had probably been introduced in extracting a very small particle of cement, which had fallen down; the rod with which this was done having been passed about $\frac{1}{10}$th of an inch below

the surface of the mercury. They disappeared under atmospheric pressure. The whole length of the mercurial column was now twenty-nine inches and a half, leaving only three inches and a half of the tube unoccupied, which was deemed but barely sufficient to prevent the communication of the heat melting the cement and destroying the exhaustion. When the air was abstracted, the junction was again just discernible. The boiling was begun as before from the top, and carried downwards to about two inches below the union of the two portions. The little air-bubbles were visibly expanded and easily passed up: the boiling was continued for a considerable time, and large bubbles of mercurial vapour, accompanied with bright green light, freely traversed the whole column. The tube was then suffered gradually to cool. Its appearance was compact and bright: a very slight haziness or discoloration was observable at the junction, but not the slightest indication of air even under exhaustion. No precipitation of moisture was perceptible in the cool portion of the tube.

It was the original intention to have completed the filling of the barometer, by boiling the remaining three inches and a half; but, upon consideration of all the circumstances, and especially of the necessity there would be of performing this under atmospheric pressure, it was concluded not again to expose the tube to so much risk. The column already boiled comes within the range of the atmospheric oscillations, and the utmost care was taken in filling the remainder, as before, *in vacuo*. The last portions of mercury were

introduced hot, and the whole was left for forty-eight hours, to take the temperature of the air. The tube was then carefully inverted in the cistern; but the mercury, notwithstanding its great body, did not descend till after it had received two or three smart concussions. This, I believe, to be the most certain proof of the complete displacement of every particle of air. The adjustments of the scale, with its nonius to the upper mark upon the tube, and of the quantity of mercury in the cistern to the line upon the float, were now easily made, and the instrument was fixed in its proper situation. Whenever the mercury vibrates in the tube, a beautiful green light flashes through the vacuum, and the crackling sound of electric excitation is heard when the finger is presented to it. Electric attraction and repulsion are also exhibited by presenting a piece of gold leaf to its influence.

Everything has been studied in this instrument to render accuracy attainable, with as little trouble as possible to the observer. The diameter of the tube renders the correction for capillary action almost unnecessary; the correction for the capacity of the cistern has been contrived to be $\frac{1}{100}$th of the result above or below the neutral point, 30·576; and a scale is engraved upon the front, of the correction to be applied for the expansion of mercury and mean dilatation of glass; by which the observation may be at once reduced to the standard temperature of 32°. A small thermometer in front of the instrument dips into the mercury of the cistern. The specific gravity of the mercury employed was carefully ascertained at

the Royal Institution, by Mr. Faraday. The temperature of the metal and the water were both 40°, and 1000 grains of the former displaced 73·4 grains of the latter: hence $\frac{1000}{73 \cdot 4} = 13 \cdot 624$.

One of my chief objects during these experiments has been to ascertain the agreement of different barometers made with equal care and independently graduated, after all the necessary corrections have been made for accidental differences. I, therefore, attended particularly to the construction of a mountain barometer for my own use, which was filled *in vacuo*, and afterwards boiled. After the process, the tube was perfect in appearance, the mercury adhered when reversed, and the electric light was very visible. The graduation was made with every care from the surface. The interior diameter of the tube is 0·15 inches, and the correction for the capacity of the cistern $\frac{1}{41}$, the neutral point 30·180. I shall here give the details of three separate comparisons of these two instruments.

Royal Society's Barometer.		Mountain Barometer.	
30·576	Temp. of Mercury 50°.	30·526	Temp. of Mercury 50°.
− ·047	Correction for Temp.	− ·047	Correction for Temp.
30·529		30·479	
+ ·006	Capillary Action.	+ ·088	Capillary Action.
30·535		30·567	
....		+ ·009	Capacity of Cistern.
30·535		30·576	

Royal Society's Barometer.		Mountain Barometer.	
29·872	Temp. of Mercury 64°.	29·849	Temp. of Mercury 70°.
− ·007	Capacity of Cistern.	− ·008	Capacity of Cistern.
29·865		29·841	
− ·082	Temp. of Mercury.	− ·098	Temp. of Mercury.
29·783		29·743	
+ ·006	Capillary Action.	+ ·088	Capillary Action.
29·789		29·831	

29·756	Temp. of Mercury 63°.	29·742	Temp. of Mercury 72°.
− ·008	Capacity of Cistern.	− ·010	Capacity of Cistern.
29·748		29·732	
− ·078	Temp. of Mercury.	− ·102	Temp. of Mercury.
29·670		29·630	
+ ·006	Capillary Action.	+ ·088	Capillary Action.
29·676		29·718	

The results of these comparisons disappointed me at first, as I had been induced to expect a much nearer accordance, after all the pains that had been taken. Upon reflection, however, I am inclined to think that the apparent discordance is in favour of the instruments, and that the difference points to an error in one of the corrections which has been overlooked. In the first place, it will be remarked that the difference ·040 inch is constant, and its cause, therefore, is probably to be sought in the only constant correction, namely, that for capillary action. The quantities allowed have been taken from Dr. Young's Table* of the depression of mercury in barometer-

* Young's *Natural Philosophy*, vol. ii. p. 669.

tubes, which was calculated from experiments. But these experiments were made with tubes in which the mercury had not been previously boiled, and a little consideration will be sufficient to show that the results must have been very much influenced by this circumstance.

The phenomena of capillary depression depend upon the balance of the attraction of the particles of the fluid for each other, and for the solid of which the tube is composed. The attraction of mercury for glass is well known to increase as the contact becomes more perfect; and, indeed, all the phenomena attending the boiling of a barometer-tube prove that this is the case. The depression in a tube, from which the air has been thoroughly expelled, must therefore necessarily be less than in one which has been filled without this precaution.

Professor Casbois, of Metz, long ago remarked, that the depression of mercury in tubes of glass depended upon the imperfection of the contact; and M. de Luc, speaking of the same fact, observes—"MM. Cassini de Thury et Le Monnier employèrent des tubes de différens diamètres, et cependant ils ne trouvèrent les différences dont parle M. de Plantade que dans les tubes que n'avoient pas été chargés au feu*."

The comparison above made would seem to indicate, that the depression is decreased one-half by boiling, and by diminishing the correction accordingly,

* De Luc, *Recherches sur l'Atmosphère*, tom. i. p. 95.

the two instruments exactly agree. By a comparison of several others, this estimate is greatly confirmed; and I have lately had an opportunity of putting it to a decisive test. Colonel Sabine, before his departure for the North Seas, requested me to assist at an examination of his barometers: two were of the mountain construction, with iron cisterns, by Newman; and one was a marine barometer, by Jones. They had all been independently graduated from the surface of the mercury, and boiled. The interior diameters of the two first were ·15 inch, and the correction for the capacities of the cisterns $\frac{1}{54}$th. The diameter of the last ·31 inch, and the correction for the capacity of the cistern $\frac{1}{11}$th. The neutral points of the three were the same, viz., 30·400.

The following is the comparison of the three instruments with the one which had been already compared with that of the Royal Society. The latter I shall call 1; the two other mountain barometers, 2 and 3, and the marine barometer, 4. The heights are the means of four observations, taken independently by different observers, who never differed more than ·005 inch.

No. 1.	No. 2.	No. 3.	No. 4.	
30·1835	30·1730	30·1845	30·1937	Temperature of Mercury alike.
·0000	− ·0042	− ·0039	− ·0187	Capacity.
30·1835	30·1688	30·1806	30·1750	
+ ·0880	+ ·0880	+ ·0880	+ ·0280	Capillary Action, by Dr. Young.
30·2715	30·2568	30·2686	30·2030	

Second Comparison.

No. 1.	No. 2.	No. 3.	No. 4.	
30·1130	30·1045	30·1087	30·1202	
−·0016	−·0054	−·0052	−·0254	Capacity.
30·1114	30·0991	30·1035	30·0948	
+·0880	+·0880	+·0880	+·0280	Capillary Action.
30·1994	30·1871	30·1915	30·1228	

It will be observed, that the three mountain barometers agree very closely together, the greatest difference from their average height being ·008 inch, while the difference of the marine barometer from the same height is, in the first comparison, ·062 inch, and in the second ·070 inch. If, however, we substitute half the correction for the capillary action, as in the case of the Royal Society's barometer, the difference is decreased one-half.

No. 1.	No. 2.	No. 3.	No. 4.	
30·1835	30·1688	30·1806	30·1750	Half the Correctio
+·0440	+·0440	+·0440	+·0140	. Capillary Action.
30·2275	30·2128	30·2246	30·1890	
30·1114	39·0991	30·1035	30·0948	
+·0440	+·0440	+·0440	+·0140	Half the Cor.
30·1554	30·1431	30·1475	30·1088	

The remaining discrepancy, I have some reason for believing, is in the measurement of the neutral point of the marine barometer.

Thus we see that the application of half the correction for capillary depression, derived from experiments upon unboiled tubes, is most applicable to boiled barometers; and from its application to tubes

of the greatly-differing diameters, ·53 inch, ·31 inch, ·15 inch, we may pretty safely conclude, that the proposition is universal.

The following Table gives the results of the experiments of Lord Charles Cavendish upon capillary depression, the correct calculation of the same by Dr. Young, and the probable amount in boiled tubes:—

TABLE XXXIX. *Correction to be applied to Barometers for Capillary Action.*

Diameter of Tube.	Cavendish.	Young.	Amount in Boiled Tubes.
Inch.	Inch	Inch.	
·60	·005	·0045	·002
·50	·007	·0074	·003
·45		·0100	·005
·40	·015	·0139	·007
·35	·025	·0196	·010
.30	·036	·0280	·014
·25	·050	·0404	·020
·20	·067	·0589	·029
·15	·092	·0880	·044
·10	·140	·1424	·070

During my experiments upon the filling and boiling of the barometer-tubes, my attention was particularly directed to the assertion of Sir Humphry Davy*, that "there is great reason to believe that air exists in mercury, in the same invisible state as in water, that is, distributed through its pores;" and to the disheartening fact, (if proved,) that absorption of air "may explain the difference of the heights of the mercury in different barometers; and seems to indi-

* *Phil. Trans.* 1822, p. 74.

cate the propriety of reboiling the mercury in these instruments, after a certain lapse of time." It is with much diffidence that I am compelled to differ from the high authority of the President upon this interesting point: but there is one observation which I made, which, I think, nearly disproves the supposition. All fluids, which are known to absorb air into their pores, invariably emit it when the pressure of the atmosphere is removed: but, upon an attentive examination of large bodies of mercury, variously heated in the vacuum of an air-pump, I never saw a bubble of air given off from the surface of the metal. Air will rise from the contact of the mercury with the glass in which it is contained, in exact inverse proportion to the care with which it has been filled, but it never rises from the surface of the mercury alone. The difficulty of properly filling a barometer-tube, I attribute to the attraction between the glass and the air, not to that between the mercury and air; and I believe that air will insinuate itself a little way between the glass and the metal at the exposed end of a boiled tube, but that this cannot happen if the end be plunged in mercury; and, consequently, that no deterioration of barometers is to be apprehended from this cause. Such a deterioration, indeed, if it had existed, must, long ago, have been detected from the instruments themselves; for, although the register of the Royal Society is not in such a state as to enable any one to reason upon its conclusions, that of the Royal Observatory of Paris, and some others, must have disclosed the fact.

With respect to the method of filling a barometer-

tube *in vacuo*, recommended above, I have little doubt that it is as accurate as the method of boiling, if performed with proper care, and it is infinitely less troublesome and hazardous. The electric light is as strong in the tube, and its appearance is in every way as perfect. There is, however, one precaution which it is proper to take, viz., to boil about an inch of mercury in the lower end of the tube, as this will prevent that concussion of the metal in its fall, which, breaking it into globules, is apt to entangle any of the residual air. At all events it will be a great improvement upon the common method, which merely consists in passing a large bubble of air up and down the tube, to collect together the smaller particles which adhere to the glass.

Indeed it is high time that more attention should be paid to the construction of meteorological instruments in general. The generality of observers are little aware of the serious inaccuracies to which they are liable. In the shops of the best manufacturers and opticians I have observed that no two barometers agree; and the difference between the extremes will often amount to a quarter of an inch: and this, with all the deceptive appearance of accuracy which a nonius, to read off to the five hundredth part of an inch, can give.

The common instruments are mere play-things, and are, by no means, applicable to observations in the present state of natural philosophy. The height of the mercury is never actually measured in them, but they are graduated one from another, and their

errors are thus unavoidably perpetuated. Few of them have any adjustment for the change of level in the mercury of the cistern, and in still fewer is the adjustment perfect: no neutral point is marked upon them, nor is the diameter of the bore of the tube ascertained: and in some the capacity of the cisterns is perpetually changing from the stretching of a leathern bag, or from its hygrometric properties. Nor would I quarrel with the manufacture of such play-things; they are calculated to afford much amusement and instruction; but all I contend for is, that a person who is disposed to devote his time, his fortune, and oftentimes his health, to the enlargement of the bounds of science, should not be liable to the disappointment of finding that he has wasted all, from the imperfection of those instruments, upon the goodness of which he conceived he had good grounds to rely. The questions, now of interest to the science of meteorology, require the measurement of the five hundredth part of an inch in the mercurial column; and, notwithstanding the number of meteorological journals, which monthly and weekly contribute their expletive powers to the numerous magazines, journals, and gazettes, there are few places, indeed, of which it can be said that the mean height of the barometer for the year has been ascertained to the tenth part of an inch. The answer of the manufacturer to these observations is, that he cannot afford the time to perfect such instruments. Nor can he, at the price which is commonly given; for few people are aware of the requisite labour and anxiety. But who would

grudge the extra remuneration for such pains? Not the man who is competent to avail himself of its application. Let the manufacturer of play-things continue, but let there also be another class of instruments which may rival in accuracy those of the astromomer.

It will, no doubt, be a part of the plan of the Committee of the Royal Society to establish a standard barometer, and to afford every facility of comparison with it; so that any person, for scientific purposes, may have an opportunity of verifying an instrument: and it is to be hoped that they may proceed one step further, and take measures for ascertaining the agreement of the instruments at all the principal observatories, not only in this country, but in other parts of the world.

Nor is it in the construction of barometers only that the meteorologist has to complain of that want of accuracy which is so essential to the progress of his science: the same carelessness attends the manufacture of the thermometer. Few people are aware that they are all, even those which bear the first makers' names, made by the Italian artists, who graduate them from one another, and never think of verifying the freezing and boiling points. The bulbs are all blown with the mouth, and very little attention is paid to the regularity of the tube. The register thermometers particularly, are shamefully deficient. Those of Six's construction are often filled with some saline solution instead of alcohol; and in the best, the spirit is not exposed long enough *in vacuo*, to disen-

gage the air with which it is mixed. The consequence is, that it is liable to become liberated, and, of course, interferes with the results. The original directions of the inventor have also been departed from, as to the proportions of the different parts, and as to the construction of the *indices.*

Those upon Rutherford's plan are universally sealed with air in their upper parts, which acts as a spring against the expansion of the column. The iron index of one is liable thereby to become oxidated, and adheres to the glass, when the mercury passes it, and it becomes entangled; while the spirit of the other being unavoidably mixed with air, when the pressure is decreased by cold it is disengaged. The air may be again dissolved by increasing the pressure before a fire, and passing the bubble backwards and forward, and, in a state of solution, it does not appear to interfere with the equability of the expansion. This, however, is not certain; and, at all events, it is liable to re-appear, and is very troublesome. These imperfections are, by no means, necessary consequences of the construction of the instruments, although the makers are very willing that they should be so considered; but it requires great care and attention to guard against them. The general mounting of the meteorological thermometers is exceptionable in every way; buried as they are in a thick mass of wood, and covered with a clumsy guard of brass, they can but very slowly follow the impressions of atmospheric temperature.

The establishment of a perfect standard thermo-

meter, which shall be accessible to all who may wish to consult it, will also, doubtless, be another object of the Committee of the Royal Society.

With respect to the change in the freezing point, which takes place in time in the best thermometers, I have lately had an unexceptionable opportunity of confirming the assertions of the French and Italian philosophers. Mr. Jones has obligingly put into my hands two thermometers of the late Mr. Cavendish, which have evidetnly been constructed with much care. The mercury in the balls of both flows freely into the tubes when reversed; and when suffered to fall sharply, strikes the ends with a metallic sound. The same *click* may be heard in the bulbs when it is permitted to fall back, and the cavity closes without the slightest speck*. They are mounted upon common deal sticks, and the graduation, which is only continued for a few degrees about the freezing point, is engraved upon a small slip of brass. The degrees are very large, and they are distinctly divided into tenths. Each degree of No. 1, occupies a space of ·208 inch, and of No. 2, ·130 inch. The scratch upon the glass for the freezing point is very visible in both. It is difficult to say for what purpose they were originally made, but evidently for some experiments upon the freezing point of water; and if they had been expressly constructed to verify the present point, they could not have been better contrived for the purpose. The bulbs of both were plunged into pounded

* These indications of a well-boiled tube are rarely to be met with in the common thermometers of the present day.

ice, in which they were left for half an hour, and the height of the mercury was carefully taken by two observers with the aid of magnifying glasses. The result of the examination was, that in No. 1 the freezing point upon the scale was 0·4° too low, and in No. 2, 0·35°. There can be little doubt, I think, that the right cause of the phenomenon has been assigned, viz., the change of form and capacity which the glass undergoes from the pressure of the atmosphere upon the *vacuum* of the tube.

But attention to the perfection of instruments will be all in vain, without a proper degree of care and system in making and recording the observations. Observers would render a much greater service to science by devoting less of their time to the actual inspection of their instruments, and more to applying the proper corrections. If the meteorologist plead want of leisure, instead of daily observations, let him record the atmospheric changes of every second or third day, but let what he does record be correct. The proper hours of the day for observation are indicated by the barometer: the maximum height of the mercurial column is about 9 A.M., the mean at 12, and the minimum at 3 P.M. If a person have time to make three observations in the day, these are the hours which he should select: if circumstances only allow of his observing twice, 9 A.M. and 9 P.M. are the proper periods: if only once, noon is the time. These fortunately happen to be, probably, the most universally convenient hours that could have been selected. In national observatories it would not be too much to expect that

observations at 3 A.M. should be added to the preceding. Even those who merely consult the barometer as a weather-glass, would find it an advantage to attend to these hours; for I have remarked, that by much the safest prognostications from this instrument may be formed from observing when the mercury is inclined to move contrary to its periodical course. If the column rise between 9 A.M. and 3 P.M., it indicates fine weather; if it fall from 3 to 9, rain may be expected.

But the meteorologist, who wishes to confer a real benefit upon science by his labours, has a much more tedious duty to perform than this. After taking the height of the barometer at the prescribed times with all possible caution, he will take care to make the proper corrections of the observations. If his instrument be not furnished with a contrivance for adjusting the level of the mercury, he will correct it according to the relative capacities of the tube and cistern: he will add the proper quantity for capillary depression, according to the diameter of the tube: and he will then reduce the height to what it would have been, if the mercury had been of the standard density at the temperature of 32°.

For the purpose of facilitating this last operation, I shall here subjoin a Table of the proper correction, calculated by Mr. Rice from the experiments of MM. Dulong and Petit upon the expansion of mercury and mean dilatation of glass:—

TABLE XL. *Correction to be applied to Barometers for Expansion of Mercury and Mean Dilatation of Glass.*

Temp.	Inches. 28·	Inches. 28·5	Inches. 29·	Inches. 29·5	Inches. 30·	Inches. 30·5	Inches. 31·	Inches. 31·5
25	+ ·017	·017	·017	·018	·018	·018	·019	·019
30	+ ·005	·005	·005	·005	·005	·005	·005	·005
35	− ·007	·007	·007	·008	·008	·008	·008	·008
40	− ·019	·020	·020	·020	·021	·021	·021	·022
45	− ·031	·032	·032	·033	·033	·034	·035	·036
50	− ·043	·044	·045	·046	·046	·047	·048	·049
55	− ·055	·056	·057	·058	·059	·060	·061	·062
60	− ·067	·068	·069	·071	·072	·074	·075	·076
65	− ·079	·081	·082	·083	·085	·086	·088	·089
70	− ·091	·093	·094	·096	·098	·100	·101	·103
75	− ·103	·105	·106	·109	·111	·114	·116	·118

At the conclusion of this Essay a Table is given of the corrections to be applied to barometers with *brass scales*, extending from the cistern to the top of the mercurial column.

By calculating the monthly means, the observer will give a still greater value to his co-operation.

Attention to these directions, in addition to the benefit which it would confer upon meteorology, would also facilitate the purposes of barometric levelling; in return for which, the detached operations of barometric mensuration should, if possible, be performed with a due regard to the prescribed hours of the meteorologist.

The observation of the barometer almost necessarily implies an inspection of the thermometer, and the height of that instrument should be recorded at the same periods; in addition to which the *maximum* and *minimum*, by register thermometers, should be care-

fully noted. The proper precautions to be taken in placing the instruments for this purpose, are now so well understood that it is needless to repeat them: they are summed up by saying that they should be sheltered from every species of radiation. The register of the force of radiation in a reflector (as described in the Essay upon Radiation,) and the power of the sun's rays upon black wool would also be particularly interesting; in addition to which, those who have the opportunity should not neglect the variations of the temperature of the sea and other deep bodies of water.

The periods of the barometric observations are also well adapted to those of the hygrometer; but the mean pressure of the aqueous atmosphere should be calculated from the dew-point at 3 P.M., and the lowest temperature at night of the sheltered thermometer. The prognostications to be derived from this instrument have been already described in the Essay upon the Hygrometer, and to these I shall only now add, that by comparing the dew-point with the third Table of the Essay upon the Climate of London, an accurate estimation may be formed of its accordance with the mean, and of the consequent probability of precipitation, change of wind, &c.

In concluding these observations, I must not, in justice, omit to state, that in all the practical details with which I have been engaged, I have met with the most ready and able assistance from Mr. Newman. He entered fully into all my views with respect to the improvement of meteorological instruments, and has bestowed much time and attention upon executing the

hints which I have suggested. His portable barometers with iron cisterns may be depended upon for the nicest experiments.

I must terminate these remarks, as I began, by an urgent recommendation to meteorologists to use standard instruments, to observe them with care, and to make all necessary corrections for accidental differences: and above all, to keep their tables upon the same scheme. Much curious information is dependent upon such an extensive plan of comparative observation, and without it the observer does little more than accumulate an overwhelming mass of crude and incorrect materials, already too large for arrangement and correction. The example has been set by the Royal Academy of Sciences of Paris, and no better model can be taken than the *Meteorological Journal* kept at their Observatory.

[Since the first publication of this Essay, directions for making and recording Meteorological and Magnetic observations have been published in a Report of the Committee of Physics, including Meteorology, printed by order of the Council of the Royal Society, and these directions have been adopted in the National Observatories. The foundation of the Meteorological part of this Report was a paper drawn up by Professor Daniell at the request of the Committee. This paper it was his intention to have published instead of the preceding Essay; as, however, it was not found amongst his papers after his death this intention was frustrated, and it was therefore judged better to reprint the original Essay. But we subjoin, from the Royal Society's Report, a Table (XLI.) of the Correction to be applied to Barometers with *brass scales*, extending from the cistern to the top of the mercurial column, to reduce the observation to 32° Fahrenheit.]

TABLE XLI. *Correction for Barometers with brass scales.*

Temp.	Inches.							
	20	20·5	21	21·5	22	22·5	23	23·5
°	+	+	+	+	+	+	+	+
0	·051	·053	·054	·055	·056	·058	·059	·060
1	·049	·051	·052	·053	·054	·056	·057	·058
2	·048	·049	·050	·051	·052	·054	·055	·056
3	·046	·047	·048	·049	·050	·052	·053	·054
4	·044	·045	·046	·047	·048	·050	·051	·052
5	·042	·043	·044	·045	·046	·048	·049	·050
6	·040	·042	·042	·044	·044	·046	·047	·048
7	·039	·040	·041	·042	·042	·044	·044	·046
8	·037	·038	·039	·040	·041	·041	·042	·043
9	·035	·036	·037	·038	·039	·039	·040	·041
10	·033	·034	·035	·036	·037	·037	·038	·039
11	·031	·032	·033	·034	·035	·035	·036	·037
12	·030	·030	·031	·032	·033	·033	·034	·035
13	·028	·029	·029	·030	·031	·031	·032	·033
14	·026	·027	·027	·028	·029	·029	·030	·031
15	·024	·025	·026	·026	·027	·027	·028	·029
16	·022	·023	·024	·024	·025	·025	·026	·026
17	·021	·021	·022	·022	·023	·023	·024	·024
18	·019	·019	·020	·020	·021	·021	·022	·022
19	·017	·018	·018	·018	·019	·019	·020	·020
20	·015	·016	·016	·016	·017	·017	·018	·018
21	·014	·014	·014	·015	·015	·015	·015	·016
22	·012	·012	·012	·013	·013	·013	·013	·014
23	·010	·010	·010	·011	·011	·011	·011	·012
24	·008	·008	·009	·009	·009	·009	·009	·010
25	·006	·007	·007	·007	·007	·007	·007	·007
26	·005	·005	·005	·005	·005	·005	·005	·005
27	·003	·003	·003	·003	·003	·003	·003	·003
28	·001	·001	·001	·001	·001	·001	·001	·001
	—	—	—	—	—	—	—	—
29	·001	·001	·001	·001	·001	·001	·001	·001
30	·003	·003	·003	·003	·003	·003	·003	·003
31	·005	·005	·005	·005	·005	·005	·005	·005
32	·006	·006	·007	·007	·007	·007	·007	·007
33	·008	·008	·008	·009	·009	·009	·009	·010
34	·010	·010	·010	·011	·011	·011	·011	·012
35	·012	·012	·012	·013	·013	·013	·013	·014
36	·013	·014	·014	·014	·015	·015	·016	·016
37	·015	·016	·016	·016	·017	·017	·018	·018
38	·017	·017	·018	·018	·019	·019	·020	·020
39	·019	·019	·020	·020	·021	·021	·022	·022
40	·021	·021	·022	·022	·023	·023	·024	·024
41	·022	·023	·024	·024	·025	·025	·026	·026
42	·024	·025	·025	·026	·027	·027	·028	·028
43	·026	·027	·027	·028	·029	·029	·030	·031
44	·028	·029	·029	·030	·031	·031	·032	·033
45	·030	·030	·031	·032	·033	·033	·034	·035
46	·031	·032	·033	·034	·035	·035	·036	·037
47	·033	·034	·035	·036	·036	·037	·038	·039
48	·035	·036	·037	·038	·038	·039	·040	·041
49	·037	·038	·039	·040	·040	·041	·042	·043
50	·038	·039	·040	·041	·042	·043	·044	·045

Temp.	Inches.							
	20	20·5	21	21·5	22	22·5	23	23·5
°	—	—	—	—	—	—	—	—
51	·040	·041	·042	·043	·044	·045	·046	·047
52	·042	·043	·044	·045	·046	·047	·048	·049
53	·044	·045	·046	·047	·048	·049	·050	·052
54	·046	·047	·048	·049	·050	·051	·052	·054
55	·047	·049	·050	·051	·052	·053	·055	·056
56	·049	·050	·052	·053	·054	·055	·057	·058
57	·051	·052	·054	·055	·056	·057	·059	·060
58	·053	·054	·055	·057	·058	·059	·061	·062
59	·055	·056	·057	·059	·060	·061	·063	·064
60	·056	·058	·059	·061	·062	·063	·065	·066
61	·058	·060	·061	·062	·064	·065	·067	·068
62	·060	·061	·063	·064	·066	·067	·069	·070
63	·062	·063	·065	·066	·068	·069	·071	·072
64	·063	·065	·067	·068	·070	·071	·073	·075
65	·065	·067	·068	·070	·072	·073	·075	·077
66	·067	·069	·070	·072	·074	·075	·077	·079
67	·069	·071	·072	·074	·076	·077	·079	·081
68	·071	·072	·074	·076	·078	·079	·081	·083
69	·072	·074	·076	·078	·080	·081	·083	·085
70	·074	·076	·078	·080	·082	·083	·085	·087
71	·076	·078	·080	·082	·083	·085	·087	·089
72	·078	·080	·082	·084	·085	·087	·089	·091
73	·079	·081	·083	·085	·087	·089	·091	·093
74	·081	·083	·085	·087	·089	·091	·093	·095
75	·083	085	·087	·089	·091	·093	·095	·098
76	·085	·087	·089	·091	·093	·095	·097	·100
77	·087	·089	·091	·093	·095	·097	·100	·102
78	·088	·091	·093	·095	·097	·099	·102	·104
79	·090	·092	·095	·097	·099	·101	·104	·106
80	·092	·094	·096	·099	·101	·103	·106	·108
81	·094	·096	·098	·101	·103	·105	·108	·110
82	·095	·098	·100	·103	·105	·107	·110	·112
83	·097	·100	·102	·104	·107	·109	·112	·114
84	·099	·101	·104	·106	·109	·111	·114	·116
85	·101	·103	·106	·108	·111	·113	·116	·118
86	·103	·105	·108	·110	·113	·115	·118	·120
87	·104	·107	·109	·112	·115	·117	·120	·123
88	·106	·109	·111	·114	·117	·119	·122	·125
89	·108	·111	·113	·116	·119	·121	·124	·127
90	·110	·112	·115	·118	·121	·123	·126	·129
91	·111	·114	·117	·120	·122	·125	·128	·131
92	·113	·116	·119	·122	·124	·127	·130	·133
93	·115	·118	·121	·124	·126	·129	·132	·135
94	·117	·120	·122	·125	·128	·131	·134	·137
95	·118	·121	·124	·127	·130	·133	·136	·139
96	·120	·123	·126	·129	·132	·135	·138	·141
97	·122	·125	·128	·131	·134	·137	·140	·143
98	·124	·127	·130	·133	·136	·139	·142	·145
99	125	·129	·132	·135	·138	·141	·144	·147
100	·127	·130	·134	·137	·140	·143	·146	·150

Temp.	Inches. 24	24·5	25	25·5	26	26·5	27	27·5	Temp.
°	+	+	+	+	+	+	+	+	°
0	·061	·063	·064	·065	·067	·068	·069	·071	0
1	·059	·061	·062	·063	·064	·065	·067	·068	1
2	·057	·058	·060	·061	·062	·063	·064	·066	2
3	·055	·056	·057	·059	·060	·061	·062	·063	3
4	·053	·054	·055	·056	·057	·058	·059	·061	4
5	·051	·052	·053	·054	·055	·056	·057	·058	5
6	·049	·050	·051	·052	·053	·054	·055	·056	6
7	·046	·047	·048	·049	·050	·051	·052	·053	7
8	·044	·045	·046	·047	·048	·049	·050	·051	8
9	·042	·043	·044	·045	·046	·046	·047	·048	9
10	·040	·041	·042	·042	·043	·044	·045	·046	10
11	·038	·039	·039	·040	·041	·042	·042	·043	11
12	·036	·036	·037	·038	·039	·039	·040	·041	12
13	·033	·034	·035	·036	·036	·037	·038	·038	13
14	·031	·032	·033	·033	·034	·035	·035	·036	14
15	·029	·030	·030	·031	·032	·032	·033	·033	15
16	·027	·028	·028	·029	·029	·030	·030	·031	16
17	·025	·025	·026	·026	·027	·027	·028	·028	17
18	·023	·023	·024	·024	·025	·025	·025	·026	18
19	·021	·021	·021	·022	·022	·023	·023	·024	19
20	·018	·019	·019	·020	·020	·020	·021	·021	20
21	·016	·017	·017	·017	·018	·018	·018	·019	21
22	·014	·014	·015	·015	·015	·016	·016	·016	22
23	·012	·012	·012	·013	·013	·013	·013	·014	23
24	·010	·010	·010	·010	·011	·011	·011	·011	24
25	·008	·008	·008	·008	·008	·008	·009	·009	25
26	·005	·006	·006	·006	·006	·006	·006	·006	26
27	·003	·003	·003	·003	·004	·004	·004	·004	27
28	·001	·001	·001	·001	·001	·001	·001	·001	28
	—	—	—	—	—	—	—	—	
29	·001	·001	·001	·001	·001	·001	·001	·001	29
30	·003	·003	·003	·004	·004	·004	·004	·004	30
31	·005	·006	·006	·006	·006	·006	·006	·006	31
32	·008	·008	·008	·008	·008	·008	·008	·009	32
33	·010	·010	·010	·010	·011	·011	·011	·011	33
34	·012	·012	·012	·013	·013	·013	·013	·014	34
35	·014	·014	·015	·015	·015	·015	·016	·016	35
36	·016	·017	·017	·017	·017	·018	·018	·019	36
37	·018	·019	·019	·019	·020	·020	·021	·021	37
38	·020	·021	·021	·022	·022	·023	·023	·023	38
39	·023	·023	·024	·024	·024	·025	·025	·026	39
40	·025	·025	·026	·026	·027	·027	·028	·028	40
41	·027	·027	·028	·029	·029	·030	·030	·031	41
42	·029	·030	·030	·031	·031	·032	·033	·033	42
43	·031	·032	·032	·033	·034	·034	·035	·036	43
44	·033	·034	·035	·035	·036	·037	·037	·038	44
45	·035	·036	·037	·038	·038	·039	·040	·041	45
46	·038	·038	·039	·040	·041	·042	·042	·043	46
47	·040	·041	·041	·042	·043	·044	·045	·046	47
48	·042	·043	·044	·045	·045	·046	·047	·048	48
49	·044	·045	·046	·047	·048	·049	·050	·050	49
50	·046	·047	·048	·049	·050	·051	·052	·053	50

Temp.	Inches.								Temp.
	24	24·5	25	25·5	26	26·5	27	27·5	
°	—	—	—	—	—	—	—	—	°
51	·048	·049	·050	·051	·052	·053	·054	·055	51
52	·050	·052	·053	·054	·055	·056	·057	·058	52
53	·053	·054	·055	·056	·057	·058	·059	·060	53
54	·055	·056	·057	·058	·059	·060	·062	·063	54
55	·057	·058	·059	·060	·062	·063	·064	·065	55
56	·059	·060	·061	·063	·064	·065	·066	·068	56
57	·061	·062	·064	·065	·066	·068	·069	·070	57
58	·063	·065	·066	·067	·069	·070	·071	·073	58
59	·065	·067	·068	·070	·071	·072	·074	·075	59
60	·068	·069	·070	·072	·073	·075	·076	·077	60
61	·070	·071	·073	·074	·075	·077	·078	·080	61
62	·072	·073	·075	·076	·078	·079	·081	·082	62
63	·074	·076	·077	·079	·080	·082	·083	·085	63
64	·076	·078	·079	·081	·082	·084	·086	·087	64
65	·078	·080	·082	·083	·085	·086	·088	·090	65
66	·080	·082	·084	·085	·087	·089	·090	·092	66
67	·083	·084	·086	·088	·089	·091	·093	·095	67
68	·085	·086	·088	·090	·092	·094	·095	·097	68
69	·087	·089	·090	·092	·094	·096	·098	·100	69
70	·089	·091	·093	·095	·096	·098	·100	·102	70
71	·091	·093	·095	·097	·099	·101	·102	·104	71
72	·093	·095	·097	·099	·101	·103	·105	·107	72
73	·095	·097	·099	·101	·103	·105	·107	·109	73
74	·097	·099	·102	·104	·106	·108	·110	·112	74
75	·100	·102	·104	·106	·108	·110	·112	·114	75
76	·102	·104	·106	·108	·110	·112	·114	·117	76
77	·104	·106	·108	·110	·112	·115	·117	·119	77
78	·106	·108	·110	·113	·115	·117	·119	·122	78
79	·108	·110	·113	·115	·117	·119	·122	·124	79
80	·110	·113	·115	·117	·119	·122	·124	·126	80
81	·112	·115	·117	·119	·122	·124	·126	·129	81
82	·114	·117	·119	·122	·124	·126	·129	·131	82
83	·117	·119	·121	·124	·126	·129	·131	·134	83
84	·119	·121	·124	·126	·129	·131	·134	·136	84
85	·121	·123	·126	·128	·131	·133	·136	·139	85
86	·123	·126	·128	·131	·133	·136	·138	·141	86
87	·125	·128	·130	·133	·136	·138	·141	·143	87
88	·127	·130	·133	·135	·138	·141	·143	·146	88
89	·129	·132	·135	·137	·140	·143	·146	·148	89
90	·131	·134	·137	·140	·142	·145	·148	·151	90
91	·134	·136	·139	·142	·145	·148	·150	·153	91
92	·136	·139	·141	·144	·147	·150	·153	·156	92
93	·138	·141	·144	·147	·149	·152	·155	·158	93
94	·140	·143	·146	·149	·152	·155	·157	·161	94
95	·142	·145	·148	·151	·154	·157	·160	·163	95
96	·144	·147	·150	·153	·156	·159	·162	·165	96
97	·146	·149	·152	·156	·159	·162	·165	·168	97
98	·148	·152	·155	·158	·161	·164	·167	·170	98
99	·151	·154	·157	·160	·163	·166	·169	·173	99
100	·153	·156	·159	·162	·165	·169	·172	·175	100

Temp.	Inches.							Temp.
	28	28·5	29	29·5	30	30·5	31	
	+	+	+	+	+	+	+	°
0	·072	·073	·074	·076	·077	·078	·080	0
1	·069	·071	·072	·073	·074	·076	·077	1
2	·067	·068	·069	·070	·072	·073	·074	2
3	·064	·065	·067	·068	·069	·070	·071	3
4	·062	·063	·064	·065	·066	·067	·068	4
5	·059	·060	·061	·062	·063	·065	·066	5
6	·057	·058	·059	·060	·061	·062	·063	6
7	·054	·055	·056	·057	·058	·059	·060	7
8	·052	·053	·054	·054	·055	·056	·057	8
9	·049	·050	·051	·052	·053	·054	·054	9
10	·047	·047	·048	·049	·050	·051	·052	10
11	·044	·045	·046	·046	·047	·048	·049	11
12	·042	·042	·043	·044	·045	·045	·046	12
13	·039	·040	·040	·041	·042	·043	·043	13
14	·037	·037	·038	·038	·039	·040	·040	14
15	·034	·035	·035	·036	·036	·037	·038	15
16	·032	·032	·033	·033	·034	·034	·035	16
17	·029	·030	·030	·031	·031	·032	·032	17
18	·026	·027	·027	·028	·028	·029	·029	18
19	·024	·024	·025	·025	·026	·026	·027	19
20	·021	·022	·022	·023	·023	·023	·024	20
21	·019	·019	·020	·020	·020	·021	·021	21
22	·016	·017	·017	·017	·018	·018	·018	22
23	·014	·014	·014	·015	·015	·015	·015	23
24	·011	·012	·012	·012	·012	·012	·013	24
25	·009	·009	·009	·009	·009	·010	·010	25
26	·006	·006	·007	·007	·007	·007	·007	26
27	·004	·004	·004	·004	·004	·004	·004	27
28	·001	·001	·001	·001	·001	·001	·001	28
	—	—	—	—	—	—	—	
29	·001	·001	·001	·001	·001	·001	·001	29
30	·004	·004	·004	·004	·004	·004	·004	30
31	·006	·006	.007	·007	·007	·007	·007	31
32	·009	·009	·009	·009	·009	·010	·010	32
33	·011	·012	·012	·012	·012	·012	·012	33
34	·014	·014	·014	·015	·015	·015	·015	34
35	·016	·017	·017	·017	·018	·018	·018	35
36	·019	·019	·020	·020	·020	·021	·021	36
37	·021	·022	·022	·022	·023	·023	·024	37
38	·024	·024	·025	·025	·026	·026	·026	38
39	·026	·027	·027	·028	·028	·029	·029	39
40	·029	·029	·030	·030	·031	·031	·032	40
41	·031	·032	·033	·033	·034	·034	·035	41
42	·034	·034	·035	·036	·036	·037	·037	42
43	·036	·037	·038	·038	·039	·040	·040	43
44	·039	·040	·040	·041	·042	·042	·043	44
45	·041	·042	·043	·044	·044	·045	·046	45
46	·044	·045	·045	·046	·047	·048	·049	46
47	·046	·047	·048	·049	·050	·051	·051	47
48	·049	·050	·051	·052	·052	·053	·054	48
49	·051	·052	·053	·054	·055	·056	·057	49
50	·054	·055	·056	·057	·058	·059	·060	50

Temp.	Inches.							Temp.
	28	28·5	29	29·5	30	30·5	31	
°	—	—	—	—	—	—	—	°
51	·056	·057	·058	·059	·060	·061	·062	51
52	·059	·060	·061	·062	·063	·064	·065	52
53	·061	·063	·064	·065	·066	·067	·068	53
54	·064	·065	·066	·067	·068	·070	·071	54
55	·066	·068	·069	·070	·071	·072	·073	55
56	·069	·070	·071	·073	·074	·075	·076	56
57	·071	·073	·074	·075	·076	·078	·079	57
58	·074	·075	·077	·078	·079	·081	·082	58
59	·076	·078	·079	·080	·082	·083	·085	59
60	·079	·080	·082	·083	·085	·086	·087	60
61	·081	·083	·084	·086	·087	·089	·090	61
62	·084	·085	·087	·088	·090	·091	·093	62
63	·086	·088	·089	·091	·093	·094	·096	63
64	·089	·090	·092	·094	·095	·097	·098	64
65	·091	·093	·095	·096	·098	·100	·101	65
66	·094	·096	·097	·099	·101	·102	·104	66
67	·096	·098	·100	·102	·103	·105	·107	67
68	·099	·101	·102	·104	·106	·108	·109	68
69	·101	·103	·105	·107	·109	·110	·112	69
70	·104	·106	·108	·109	·111	·113	·115	70
71	·106	·108	·110	·112	·114	·116	·118	71
72	·109	·111	·113	·115	·117	·119	·120	72
73	·111	·113	·115	·117	·119	·121	·123	73
74	·114	·116	·118	·120	·122	·124	·126	74
75	·116	·118	·120	·122	·125	·127	·129	75
76	·119	·121	·123	·125	·127	·129	·131	76
77	·121	·123	·126	·128	·130	·132	·134	77
78	·124	·126	·128	·130	·133	·135	·137	78
79	·126	·128	·131	·133	·135	·137	·140	79
80	·129	·131	·133	·136	·138	·140	·143	80
81	·131	·134	·136	·138	·141	·143	·145	81
82	·134	·136	·138	·141	·143	·146	·148	82
83	·136	·139	·141	·143	·146	·148	·151	83
84	·139	·141	·144	·146	·149	·151	·154	84
85	·141	·144	·146	·149	·151	·154	·156	85
86	·144	·146	·149	·151	·154	·156	·159	86
87	·146	·149	·151	·154	·157	·159	·162	87
88	·149	·151	·154	·157	·159	·162	·165	88
89	·151	·154	·156	·159	·162	·165	·167	89
90	·153	·156	·159	·162	·164	·167	·170	90
91	·156	·159	·162	·165	·167	·170	·173	91
92	·158	·161	·164	·167	·170	·172	·175	92
93	·161	·164	·167	·170	·172	·175	·178	93
94	·163	·166	·169	·172	·175	·177	·180	94
95	·166	·169	·172	·175	·178	·180	·183	95
96	·168	·171	·174	·178	·181	·183	·186	96
97	·171	·174	·177	·180	·183	·186	·189	97
98	·173	·176	·179	·183	·186	·188	·191	98
99	·176	·179	·182	·185	·188	·191	·194	99
100	·178	·181	·184	·188	·191	·194	·197	100

ON THE

GRADUAL DETERIORATION OF BAROMETERS,

AND THE

MEANS OF PREVENTING THE SAME.

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[*Reprinted from the Second Edition.*]

IN my previous remarks upon the construction of barometers, I have stated my reasons for differing from the high authority of the President of the Royal Society, upon the *cause of the existence of elastic matter in barometer tubes,* suggested by him in a paper upon "the electrical phenomena exhibited in vacuo," and published in the *Philosophical Transactions* for the year 1822. Sign. Bellani also arrived at the same conclusion as myself, from a series of experiments which he undertook, expressly to determine whether the air or vapour, the last portions of which are found to remain so obstinately in barometers and thermometers, is introduced with the mercury, or is a portion of that which originally occupied the tube before the introduction of the metal. The conclusion he comes to is, that it is always a portion of that which previously adhered to the glass, and *that mercury is utterly incapable of absorbing either air or moisture.* One of his experiments is so simple, and at the same time so conclusive, that I cannot refrain from giving a short account of it. He filled a barometer tube, and boiled

it very carefully, and then prepared a funnel made of a small capillary tube, which reached through the mercury in the barometer tube to the closed end, and was enlarged at the top. When introduced, it had been recently made, and was perfectly dry. Some mercury was then agitated in a bottle with water and air, and afterwards dried by means of filtering paper, and afterwards passing it through paper cones, three or four times, into dry vessels. A little of this mercury was poured into the funnel-tube, and the air extracted by means of a fine wire, so that the column was continuous. So much of this prepared mercury was then poured in as fully to displace the mercury which had been boiled in the tube. The barometer was found under the same circumstances to stand exactly at the same height as before; and, when the mercury was heated, none of those bubbles appeared which arose on the first boiling*.

Still further to illustrate this subject, which I thought of the highest importance, and to ascertain the difference of capillary action in boiled and unboiled barometer-tubes, I undertook the following experiments. The apparatus which I made use of consisted of an upright pillar of brass, standing upon a mahogany foot, upon which two horizontal arms of unequal lengths were made to slide; at the extremity of each of these a steel needle, with a fine point, was fixed perpendicularly downwards. These points could be

* *Giornale de Fisica*, vol. vi. p. 20; or see *Quarterly Journal of Science*, vol. xv. p. 371.

adjusted to the same plane, or their relative distance be measured, by means of a nut and screw upon the pillar, which carried a *nonius;* and the slightest contact of these points with the clean surface of a basin of mercury was instantly perceptible. I satisfied myself, by repeated trials, that the adjustment might be depended upon to the one-thousandth part of an inch. I made a contrivance to hold a glass tube perpendicularly immersed in a basin filled with mercury; and when one of the steel points was made to touch the surface of the fluid in the tube, and the other the surface in the basin, the depression of the former was accurately measured by the *nonius.* In this manner I determined the capillary action of several tubes, varying in their diameters from one-tenth to six-tenths of an inch. The results agreed as nearly as possible with Dr. Young's table, calculated from the experiments of Mr. Cavendish. The end of the tubes, opposite to those at which the measures had been taken, were then hermetically sealed, in such a manner as to be readily re-opened under mercury: they were immediately filled with mercury, and carefully boiled. I expected to be able to ascertain the differences of depression by opening them in the basin of mercury, and proceeding as before. The experiment was performed as soon after the operation of boiling as the mercury in the tube had cooled down to the temperature of that in the basin. At first the attraction between the mercury and the glass appeared to be perfect, and no depression could be perceived. When, however, the tubes were left some time exposed, either

before or after they were opened, the air and moisture insinuated themselves between the metal and the glass, and an immediate depression was the consequence. This depression increased gradually, till at length it became fixed at the exact point of that of the unboiled tube. The progress of this effect was easily perceptible with a magnifying glass, and was rendered still more visible by heating the tube, when air-bubbles were immediately detached. This is obviously the same effect as that described by Sir H. Davy, in his paper before alluded to, in which he says that, "on keeping the stop-cock of one of the tubes, used in the experiment on the mercurial vacuum, open for some hours, it was found that the lower stratum of mercury had imbibed air, for when heated *in vacuo* it emitted it distinctly from a space of a quarter of an inch of the column; smaller quantities were disengaged from the next part of the column, and its production ceased at about an inch high in the tube." Now I conceive that the fact above related absolutely proves that the air had insinuated itself between the mercury and the tube, and shows that there is no "reason to believe that this air existed in mercury in the same invisible state as in water, that is, distributed through its pores." For, if the latter had been the case, the mercury, which contained no air after being boiled, would, from its greater density, have sunk in the tube, when surrounded by mercury which had not been boiled, and would have risen gradually as it became saturated with air. I am justified in drawing the conclusion from the contrary effect, that the air had

insinuated itself between the metal and the tube; for the capillary depression is known to be in inverse proportion to the affinity of the fluid for the containing tube, and nothing could have affected that affinity in the case before us, but the gradual interposition of a thin stratum of air and moisture.

Having thus traced and measured the progress of the air down the sides of small tubes filled with mercury, and boiled with the greatest care, I was naturally led to suspect that the same action might take place in barometers, to their gradual deterioration. I soon saw reasons to conclude that such a process actually was going on in the most carefully constructed instruments, and that in time, air would thus insinuate itself into the best Torricellian *vacuum*. In my paper upon the construction of the barometer, I have given all the particulars of the making of two barometers, in which every precaution was used to dispel every particle of air. One of these, it will be recollected, was of very large dimensions, and was fixed up in the apartments of the Royal Society, under the superintendence of the Meteorological Committee; the other was of the mountain construction, and intended for my own use: the agreement between these two instruments, when all corrections were made for the differences in their sizes and forms, was very perfect, and proved that the care which had been bestowed upon them had not been thrown away. In the latter, however, I lately remarked that a small quantity of air had ascended into the *vacuum*. I could not discover any way in which this could have obtained admission; but, attributing it

to accident, I laid it aside, and thought no more of it till the present experiments recalled it to my recollection. By a singular coincidence I was, about this time, informed that the barometer of the Royal Society had assumed a very remarkable appearance, and that the mercurial column, which was originally perfectly bright and compact, now seemed dull and speckled. I immediately proceeded to examine it carefully, aud I at once perceived that it was copiously studded with minute air-bubbles. As far as the mercury was exposed to view, the specks could be traced decreasing in size from the upper to the lower part. The manner in which this instrument is fixed rendered it impossible to suspect that this air could have obtained admission by any accident; for, unlike the mountain-barometer, the column of metal is exposed to no oscillations but such as arise from differences of atmospheric pressure. I was myself quite satisfied, and those who have read the account of the precautions taken in filling the tube will also, I think, be satisfied, that this air was not left at its original construction; and the manner of its intrusion is, I think, pointed out by the experiments which I have detailed.

While I was occupied with these considerations, and sufficiently vexed to find that all my care had been thrown away, it occurred to me that I had, in the course of my experience, observed a phenomenon, which was calculated to throw some light upon the present question; namely, that gases were more readily preserved from mixture with atmospheric

air over water than over mercury. I was unable to refer to any notes of experiments to confirm this suspicion, but I proposed the question to Mr. Faraday, who, I made no doubt, from his great accuracy and experience, must have made the observation, if it were founded in fact. Without at the time having any knowledge of the ulterior object which I had in view, he at once answered me, that mercury, he believed, would not confine gases for a long period so well as water; and he thought that, by referring to his note-book, he could furnish me with the particulars of a case in point. He accordingly did me the favour to extract the following particulars:—

In June, 1823, he made a mixture of one volume of oxygen and two volumes of hydrogen; with this he filled five *dry* bottles over mercury, and also four bottles over water. He left the glasses inverted over mercury and water, placing three mercury and two water bottles in the windows, so as to receive the sun's rays and day-light; and two mercury and two water bottles he placed in a dark place. In July, 1824, he examined the bottles; the water bottle in the light contained hydrogen and some common air, and there was no alteration of volume; the mercury bottle in light contained common air only. The water bottles in the dark place showed no alteration of volume, and the air contained in them proved to be the *original mixture;* the mercury bottles in the same situation contained *nothing but common air.*

Hence it appears that a fluid which has attraction enough for glass, to enable it to wet its surface, effec-

tually prevents the passage of gases into or out of vessels, of that substance; while a fluid which does not wet the surface permits their slow penetration. The case of the confined air is exactly analogous to that of the barometer; for its escape and the admission of the atmospheric air can only be in virtue of the law discovered by Mr. Dalton, that the gases act as *vacua* to one another. The inference is also pretty strong, that the infiltration takes place along the surface of the glass, and not through the pores of the fluid.

It has been attempted to controvert this conclusion, by the observation that gases have been preserved a considerable time by mercury; but when it is considered that the slightest film of moisture, or any foulness of the mercury will form a connexion between the metal and the glass, the objection can be of no avail, unless these circumstances have been attended to. To ensure the maximum of the effect which I have been describing, it is necessary that both glass and mercury should be in the driest and cleanest possible state; that is to say, exactly in the state in which they exist in a well-made barometer.

In consequence of doubts which were thrown over the fact, in the course of some discussions which arose upon the subject, Mr. Faraday was induced to repeat the experiment in the most careful manner, and the following are the results as recorded by himself.

"Two volumes of hydrogen gas were mixed with one volume of oxygen gas, in a jar over the mercurial trough, and fused chloride of lime introduced, for the purpose of removing hygrometric water. Three glass

bottles, of about three ounces capacity each, were selected for the accuracy with which their glass stoppers had been ground into them; they were well cleaned and dried, no grease being allowed upon the stopper. The mixture of gases was transferred into these bottles over the mercurial trough, until they were about four-fifths full, the rest of the space being occupied by the mercury. The stoppers were then replaced as tightly as could be, the bottles put into glasses in an inverted position, and mercury poured round the stoppers and necks, until it rose considerably above them, though not quite so high as the level of the mercury within. Thus arranged, they were put into a cupboard which happened to be dark, and were sealed up. This was done on June 28, 1825, and on September the 15th, 1826, after a lapse of fifteen months, they were examined. The seals were unbroken, and the bottles found exactly as they were left; the mercury still being higher on the inside than the outside. One of them was taken to the mercurial trough, and part of its gaseous contents transferred; upon examination it proved to be common air, no traces of the original mixture of oxygen and hydrogen remaining in the bottle. A second was examined in the same manner; it proved to contain an explosive mixture. A portion of the gas introduced into a tube, with a piece of spongy platinum, caused dull ignition of the platinum; no explosion took place, but a diminution to rather less than one-half. The residue supported combustion a little better than common air. It would appear, therefore, that nearly a half of the mixture of oxygen

and hydrogen had escaped from it, and been replaced by common air. The third bottle, examined in a similar manner, yielded also an explosive mixture, and upon trial was found to contain nearly two-fifths of a mixture of oxygen and hydrogen, the rest being a very little better in oxygen than common air.

"There is no good reason for supposing that this capability of escape between glass and mercury is confined to the mixture here experimented with; probably every other gas, having no action on the mercury or the glass, would have made its way out in the same manner. There is every reason for believing that a small quantity of grease round the stoppers would have made them perfectly tight*."

I also repeated the experiment with the following variations. I inclosed a portion of pure hydrogen in a glass jar, standing over mercury, carefully preserving the same level both on the inside and the out. I then passed a lump of spongy platinum into the jar, which floated upon the surface of the metal, and in this condition the jar was carefully put by in a dark cupboard. At the expiration of thirteen months, it was examined, when it was found that the mercury within the jar had risen an inch above the level of that without. The atmospheric air had evidently insinuated itself between the glass and the metal; and the oxygen, combining with the hydrogen, from the action of the platinum, had created a partial vacuum, and caused the mercury to rise.

* *Quarterly Journal of Science*, vol. xxii. p. 220.

I was no sooner convinced that the most carefully constructed barometers were liable to a slow and gradual deterioration, in the manner which I have indicated, than I endeavoured to find a remedy for the evil; without which, it is clear, that some of the most interesting problems of meteorology must be for ever left in a state of vagueness and uncertainty. For a long time I despaired of success; but I was fortunate enough at length to discover an effectual method of preserving the Torricellian *vacuum*.

I soon perceived that the only possibility of effecting the object which I had in view, consisted in finding out some method of making the mercury *wet* (if I may be allowed the term) the tube in which it is contained. I was fearful, at first, that all the substances to which its attraction is sufficiently strong for this purpose, would be so much acted upon as to become disintegrated or dissolved. I, however, fortunately recollected that, in some experiments in which I was formerly engaged, platinum, immersed in boiling mercury, became completely coated by it, and afterwards retained its coating for a long time. I repeated the experiment with some platinum foil, and found it to succeed perfectly. The mercury adhered strongly to the foil, and the latter, after a long immersion, was found to have lost none of its tenacity. I availed myself of this property in the following way:—I caused a small thin piece of platinum tube to be made about the third of an inch in length, and of the diameter of the glass tube; this was carefully welded to its open end, so that the barometer tube terminated in a

ring of platinum. The tube was filled and boiled as usual, and the infiltration of air was completely prevented by the adhesion of the mercury, both to the interior and exterior surface of the platinum guard. I have no doubt that a mere ring of wire welded, or even cemented upon the exterior surface of the glass, which would be a much easier and less expensive operation, would be a sufficient protection, as the slightest line of perfect contact must effectually arrest the passage of the air: but in the first attempt I was desirous that the experiment should be tried in the most perfect manner. When a piece of glass, armed either with a ring or tube, is immersed in mercury, the effect is easily perceived; instead of any depression being visible around it, the mercury may be lifted by it considerably above its proper level. Time, of course, alone would fully confirm the efficacy of the guard; but as far as the experiments have gone, they have been completely satisfactory.

Hydrogen gas introduced into a glass jar with spongy platinum, exactly in the same manner as before described, except that the edge of the jar was protected by a rim of platinum wetted with mercury, was completely cut off from any mixture of the atmosphere, and the mercury maintained its level without change.

It was long before I could find evidence of the deterioration of barometers in the numerous registers that are kept of their oscillations: few have been continued for a sufficient length of time, with the same instruments, to answer this purpose satisfactorily.

Instances abound of observers having taken the pains to re-boil their barometers, in consequence of air having obtained admission, in some unknown way which has always been attributed to accident; but the fact of their gradual deterioration cannot, in this way, be established, by modern observations, so completely as might have been supposed.

The Register of the Royal Observatory at Paris, published in the *Annales de Chimie*, was not commenced until the year 1816; a period which is not sufficient so far to neutralize the annual oscillation as to afford the means of a satisfactory comparison. Mr. Howard, however, in his work upon the climate of London, states the mean height of the Royal Society's barometer for ten years, from 1797 to 1806, to be 29·882 inches, while for the ten succeeding years, it is only 29·849 inches, which gives a depression of ·033 inches in that interval.

The observations of the following ten years will not, I fear, be available in the same comparison, from the carelessness with which they have been made.

The difference in the height of the old and new barometer, which have now been placed side by side, was, in the latter part of the year 1824, ·07 inch, upon a mean of twenty observations; the new barometer standing upon the average so much higher than the old one. Whether this be wholly owing to deterioration, it is not possible to say; for the old barometer does not appear to have been boiled: but from the well-known accuracy of Mr. Cavendish, under whose superintendence it was constructed, it is impossible

not to ascribe a great portion of it to this cause. The mercury of this instrument is now thickly studded with air-bubbles of much larger size than those of the new barometer; and when I last examined it, some of them were just upon the point of making their escape.

In the *Ephemerides* of the Meteorological Society of the Palatinate, however, of which I have given an account in a previous Essay, I found what I had long sought amongst modern observations. The first astronomers of the continent did not at that time think the science of Meteorology beneath their notice, and themselves attended to the irksome labour of registering the indications of the instruments, and calculating the mean results. Whoever will take the trouble of examining these faithful and laborious records, must come to the conclusion, that this branch of natural knowledge, not only has made no progress since the unfortunate dissolution of this Society, but has seriously retrograded; both as to the accuracy of the instruments of research, and the proper method of pursuing the investigation.

From the immense repository of these volumes I have selected eight registers*, in which the same instruments, all carefully compared together, were used during the greatest length of time; and from them I have extracted the following mean annual heights of

* These were the only instances which were calculated to throw any light upon the subject, from the length of time during which they were continued.

the different barometers The observations were taken three times in the day, and the means are calculated from all the observations:—

The FIRST series is that of Mannheim, which consists of twelve years, from 1781 to 1792 inclusive: this I have divided, in the following Table, into two periods of six years each. The height of the barometer is registered in French inches, lines, and tenths:—

Year.	Ins.	Ls.	Tenths.	Year.	Ins.	Ls.	Tenths.
1781	27	9	9	1787	27	9	8
1782	27	9	3	1788	27	9	6
1783	27	9	6	1789	27	8	3
1784	27	9	1	1790	27	9	2
1785	27	9	9	1791	27	8	9
1786	27	9	4	1792	27	7	5
Mean	27	9	5	Mean	27	8	8

From this it appears that the mean of the last six years is ·7 of a line, or ·062 in. English, lower than that of the first six.

The SECOND series is that of Padua for the same twelve years, divided into similar periods.

Year.	Ins.	Ls.	Tenths.	Year.	Ins.	Ls.	Tenths.
1781	28	0	84	1787	28	2	1
1782	28	1	05	1788	28	1	5
1783	28	1	65	1789	28	1	46
1784	28	1	2	1790	28	2	7
1785	28	1	68	1791	27	11	2
1786	28	1	7	1792	27	10	1
Mean	28	1	3	Mean	28	0	8

The result of this comparison is, that the mean of the last six years is lower than the first six ·5 of a line, or ·044 English inch.

The THIRD series is that of Rome, in which, how-

ever, the first year is deficient, the observations not having been commenced till the year 1782.

Year.	Ins.	Ls.	Tenths.	Year.	Ins.	Ls.	Tenths.
1781				1787	28	0	6
1782	27	10	49	1788	28	0	3
1783	27	10	71	1789	27	9	3
1784	27	11	7	1790	27	9	0
1785	28	0	2	1791	27	10	2
1786	28	0	5	1792	27	8	3
Mean	27	11	5	Mean	27	10	2

The average of the last six years is here lower than that of the first five 1 line ·3, or ·114 English inch.

The FOURTH series is that of Buda, which likewise wants the first year.

Year.	Ins.	Ls.	Tenths.	Year.	Ins.	Ls.	Tenths.
1781				1787	27	5	98
1782	27	5	76	1788	27	6	2
1783	27	6	09	1789	27	3	5
1784	27	5	89	1790	27	6	5
1785	27	5	90	1791	27	5	9
1786	27	5	85	1792	27	4	6
Mean	27	5	8	Mean	27	5	4

The difference is here ·4 line, or ·035 English inch.

The FIFTH series is that of Brussels, which, however, consists only of eight years, wanting the four first.

Year.	Ins.	Ls.	Tenths.	Year.	Ins.	Ls.	Tenths.
1785	27	10	72	1789	27	8	7
1786	27	9	98	1790	28	0	9
1787	27	10	0	1791	27	9	9
1788	27	0	5	1792	27	9	9
Mean	27	10	8	Mean	27	10	3

The difference between the means of the first and second four years is ·5 line, or ·044 English inch.

The SIXTH series is taken from a higher station; viz., Munich. The first six years are complete, but the eighth is wanting.

Year.	Ins.	Ls.	Tenths.	Year.	Ins.	Ls.	Tenths
1781	26	5	69	1787	26	6	3
1782	26	5	01	1788			
1783	26	5	35	1789	26	3	8
1784	26	5	50	1790	26	6	9
1785	26	4	99	1791	26	4	8
1786	26	4	88	1792	26	2	8
Mean	26	5	2	Mean	26	4	9

The mean of the last five years is lower than that of the first six ·3 line, or ·026 English inch.

The SEVENTH series is from the summit of Peisenberg, a mountain in Bavaria.

Year.	Ins.	Ls.	Tenths.	Year.	Ins.	Ls.	Tenths
1781	25	0	14	1787	24	11	89
1782	24	11	27	1788	24	11	73
1783	24	11	42	1789	24	11	09
1784	24	11	03	1790	25	0	1
1785	24	11	36	1791	24	11	28
1786	24	11	07	1792	24	8	9
Mean	24	11	3	Mean	24	11	0

The number of years is complete, and the mean of the first six is ·3 line higher than that of the last six, or ·026 English inch.

The EIGHTH and last series is taken from the summit of Mount St. Gothard. The first year only is deficient.

Year.	Ins.	Ls.	Tenths.	Year.	Ins.	Ls.	Tenths
1781				1787	21	10	2
1782	21	8	91	1788	21	9	0
1783	21	10	0	1789	21	9	9
1784	21	9	3	1790	21	10	3
1785	21	9	7	1791	21	8	0
1786	21	9	24	1792	21	7	4
Mean	21	9	4	Mean	21	9	1

The mean of the last six years is lower than that of the first five ·3 line, or ·026 English inch.

All these examples clearly concur in establishing the supposition of the gradual depression of the mercurial column by the infiltration of the air. There is also another conclusion, derivable from the same facts, which might have been anticipated from theory,—namely, that the amount of the effect depends, in some degree, upon the elasticity of the atmosphere in which it takes place. The five series of observations whose mean pressure is 29·235 in. English, show an average depression of ·059 inches in twelve years; while the three series, whose mean pressure is 25·977, exhibit a depression of only ·026 inches in the same interval.

From the same valuable record of facts I have also derived a strong confirmation of my opinion of the manner in which the air gains access to the vacuum of the barometer,—that is to say, that it is by means of the glass, and not of the mercury. While I quote the observation in support of my ideas upon this subject, it will at the same time serve for a specimen of the skill and exactness with which all the proceedings of the Society were regulated. The observation occurs in the directions given by the Secretary Hemmer for

boiling the mercury in thermometers. He thus expresses himself,—"Notatu perquam dignum hoc in labore est, nihil ingentis illius vis bullarum aërearum conspici, quæ, ubi mercurius sine igne immissus fuit, inter hunc et vitrum in coctione apparere solent, *manifesto indicio, eas non tam a mercurio quam a vitro provenire,* cujus parietibus adhærebant, quemadmodum in universum omnes corporum superficies densiore aëris lamina stipatas esse et ratio et experientia evincunt. Hanc aëris massam jam tum a cylindro expuleram, cum exiguam hydrargyri portionem initio immissam fortius ebullire facerem unde quæ in secunda coctione in conspectum veniebant bullæ admodum raræ erant*."

I have lately been directed by my friend Mr. R. Phillips, to another very singular confirmation of my ideas upon this interesting subject. The authority upon which this confirmation rests is that of Dr. Priestley, whose acuteness of observation few, I

* There is a defect which may often be observed in old looking-glasses, which may probably be referred to the same cause as the deterioration of barometers. I allude to a dulness which takes place in large spots over their surface, and which generally seems to radiate from the centre. I have frequently remarked this in the very old mirrors in some of the palaces upon the Continent. I imagine that this arises from the slow insinuation of air by the edges, or some accidental crack in the metal at the back of the glass. It is also, I understand, well known to the dealers in mirrors, that when placed against a damp wall, looking-glasses are particularly liable to become cloudy; and it is most likely that moisture greatly facilitates the action to which I have been referring.

imagine, will presume to doubt. The following extract is taken from the third volume of his *Observations on Air* (p. 236, and sequel), published in 1786:—

"In the course of these experiments with the sun, I observed a remarkable source of fallacy with respect to the increase of the quantity of air confined by mercury, when there is so much moisture in the inside as to be subject to sudden dilations and compressions. For a considerable quantity of common air would get into the inside of the vessel when there was the depth of an inch of mercury on the outside of it, and of two or three inches within. In these circumstances I have seen more than an ounce-measure of external air gain admission in less than one minute. This must have been occasioned by the mercury never being in perfect contact with glass; so that when the mercury was in a state of undulation, the air that was confined between it and the glass was continually protruded, and more air from the atmosphere was forced into its place, by the same pressure which supported the column of mercury within the glass. This effect I prevented by having a quantity of water upon the mercury on the outside of the vessel. For this would be in perfect contact with the glass; and in this case I never found either air or water to get into the vessel to disturb my experiment."

From these few facts thus briefly, but clearly, described, the whole of my conclusions with regard to the barometer might have been deduced with as much justness as from the more extended and varied observations upon which I have hitherto rested them.

If mercury, in Dr. Priestley's experiments, could not be brought in perfect contact with glass, neither in the common construction of a barometer can it so be brought. And as, when the mercury in his jars was in a state of undulation, the air that was confined between the two was continually protruded; so, in the barometer, will it ascend by the continual oscillations and vibrations to which it is exposed.

Again, Dr. Priestley argued, that a fluid which would be in perfect contact with the glass would effectually interrupt this action; and he accordingly found that when he put a quantity of water upon the mercury, on the outside of the vessel, neither air nor water got in to disturb his experiments. It follows, therefore, that if perfect contact between the mercury and any complete circle of the barometer tube can be produced, the air will be effectually prevented from ascending into the vacuum. I have already described an easy method of producing this contact.

The time which has elapsed since my first proposition and application of the guard to barometers enables me now to add the testimony of experience to its sufficiency and permanency. At the expiration of nearly three years from its adoption, the first instrument to which it was applied was lately examined and opened in the presence of several scientific gentlemen. The mercurial column from top to bottom was found perfectly bright and free from specks or air-bubbles, and the platinum ring as sound as on the first day when it was fixed and thoroughly *wet* with the mercury. Upon wiping the fluid off, the platinum exhi-

bited the original marks of the hammer upon it; so perfectly free was it from any signs of corrosion or disintegration! Thus has time removed the only remaining doubt about the ultimate solution of the platinum by the mercury, and confirmed the conclusion which I originally drew from the experiment with the thin platinum foil.

AN ESSAY

ON

THE CLIMATE OF LONDON.

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After the very interesting and laborious work of Mr. Howard, upon the climate of London, it may, at first sight, appear presumptuous in me to claim attention upon a subject which has been so ably and so extensively pre-occupied: but when it is considered that that able philosopher was unprovided with any sufficient means of measuring the quantity, or estimating the changes of the sea of vapour which necessarily permeates and pervades every part of the great aërial firmament; and when it is borne in mind, that one of the main springs of all the wonderful motions of the air, and the changes of the weather, is the slow and silent influence of the aqueous steam; I shall be excused for attempting to elucidate, from experiments, a part of the subject so important, but, hitherto, so neglected.

Its connexion with the vegetable kingdom, and with all the most important processes of the agriculturist, must be evident to the most superficial observer; and it is more than probable, that it will be found of equal importance to those who make a study of the complicated processes of the animal economy.

It has ever been a favourite speculation with philosophers to trace in the constitution of the atmosphere the origin of some of the diseases which affect the human race. The discovery of pneumatic chemistry, and the new means of questioning nature which it put into their hands, seemed at first to promise a solution of this interesting problem; and hopes were entertained that the cause of epidemic and local complaints might be found in the varying elements of the compound air we breathe. The eudiometric processes which were immediately instituted and repeated in every part of the world, proved, however, the unvarying proportions of the permanent gases of which it is composed. It is not, therefore, irrational to suppose that an accurate method of estimating the varying quantity of aqueous vapour in the elastic medium which surrounds us, which is the chief fluctuating ingredient of its composition, may lead to some useful hints upon this important subject. Certain it is, that some indications of this kind may be perceived even by the healthy, and by those who are not conversant with the progress of disease. There are days on which even the most robust feel an oppression and languor, which are commonly and justly attributed to the weather; while on others they experience exhilaration of spirits, and an accession of muscular energy. The oppressive effect of close weather and sultry days, may probably be accounted for from the obstruction of the insensible perspiration of the body, which is prevented from exhaling itself into the atmosphere, already surcharged with moisture; while unimpeded transpiration

from the pores, while the air is more free from aqueous vapour, adds new energy to all the vital functions. In bodies, debilitated by disease, indeed, the contrary effects may be produced: they may be unable, from weakness, to support the drain of free exhalation which is exhilarating to the healthy; and hence probably arises the benefit of warm sea-breezes in cases of consumption and diseases of the lungs. Observations upon climate, with a more particular regard to the hygrometric state of the atmosphere, may reasonably be expected, amongst other certain advantages, to throw some light upon the treatment of these complaints; and may, perhaps, teach us to construct an artificial atmosphere, of greater efficacy than any that has yet been recommended, in cases when the relief of local change may be impossible.

[The averages of seventeen years' observations (from 1826 to 1842 inclusive), from the Journal of Meteorological Observations, made in the garden of the Horticultural Society at Chiswick, have furnished materials for the following Essay. These averages have been carefully taken for the whole number of years, as well as for the separate months.

The Meteorological Journal of the Horticultural Society was commenced at the suggestion of Professor Daniell, on a plan furnished by him, and with instruments constructed under his immediate superintendence. In the year 1825, it was carried on with such instruments as were quickly attainable; but the observations for the year 1826, and the subsequent years, were made with the most perfect instruments that

could be procured,—"the object being to give the Register such a character for accuracy as would render it not only useful for the purposes of horticulture, but for the deeper researches of those men of science, whose attention, it was known, was at the time particularly directed to the subject."

In the *Transactions of the Horticultural Society*, vol. vii. p. 97, is a "Report on the Instruments employed in, and on the plan of a Journal of, Meteorological Observations, kept in the Garden of the Horticultural Society at Chiswick," from which the following information has been obtained:—

The barometer was made by Mr. John Newman, of Regent-street. "The internal diameter of the tube is 0·45 inch, and the capacity of the cistern has been so adjusted, that a rise or fall of 1 inch in the former makes a difference of 0·01 inch in the level of the mercury in the latter." "The tube is armed at the bottom with a platinum cap, perforated with a hole of one-eighth of an inch in diameter, which is sufficiently large to admit of the mercury flowing in and out with perfect freedom. This platinum guard has been well wetted with mercury, according to the suggestion of Mr. Daniell." The correction for capillary action does not exceed 0·009 inch, and is constantly applied to the observations.

"The cistern, which is turned in mahogany, is lined with iron. The tube dips 1·1 inch below the surface of the mercury, and a thermometer is inserted in it to mark its temperature. There is also a float which corresponds with a fixed mark when the column

stands at the neutral point. The observations are made by means of a vernier carrying an index both before and behind the tube, the coincidence of which with the highest point of the surface of the mercury, which is always more or less convex, is easily ascertained. The proper correction is always applied for the varying temperature of the mercurial column, and the entry in the register is the actual pressure of the atmosphere at the station, as it would be measured by a column of mercury of the temperature of 32° Fahr.

"The barometer is firmly fixed against the wall of an apartment, at the back of the small green-house in the experimental garden, which is otherwise used as a seed-room; the window and door of the room open to the north, and there is no fire-place in it. Its position is nearly 14 feet above the mean level of high water in the Thames at Chiswick.

"The observations with the barometer are made at three periods of the day, viz., morning, noon, and night.

"A Daniell's hygrometer is used for ascertaining the state of the vapour in the atmosphere. The naked ball is formed of black glass, and the observations are made three times in the day, at the same periods as those with the barometer.

"The register thermometers are of Rutherford's construction, and made by Mr. Newman. Those by which the maximum and minimum of the temperature of the air in the shade are ascertained are placed in an open spot in the Arboretum, screened from the rays of

the sun, and sheltered from terrestrial radiation by a kind of umbrella of oiled cloth; they are attached to the northern side of the post which supports the umbrella, and stand four feet from the ground. That by which the maximum of heat is ascertained is filled with mercury; the one applied to registering the minimum of heat is a spirit thermometer.

"In addition to these, two other register thermometers of the same construction are used. The first is of mercury, and the ball is covered with black wool. It is placed within four feet of a garden wall, pointing to the south, about two inches from a bed of garden mould. It registers the greatest degree of heat under the influence of the sun. The second is of spirit; its ball is also covered with black wool, and is fixed in the focus of a parabolic metallic speculum, and exposed to the full aspect of the sky. It registers the maximum degree of cold arising from radiation in such a situation. It is placed in the Arboretum, near the first described thermometer.

"The rain-gauge is made according to Mr. Howard's directions, in his work upon the climate of London; it stands upon the level of the ground in the experimental garden. The quantity of rain is registered daily.

"The plan pursued in recording the observations is similar to that proposed by Mr. Daniell in his Essays. The objects to be recorded being,—

"I. The state of the barometer, hygrometer, and weather, at the three periods of observation before mentioned.

"II. The maximum and minimum of temperature in each day, distinguishing the temperature of radiation from the common temperature of the air.

"III. The direction and force of the wind.

"IV. The amount of rain.

"V. General remarks on the state of the weather during each month, with the means of all the daily observations, showing the

Mean pressure.

Mean temperature.

Mean dew-point.

Mean force of vapour.

Mean degree of dryness.

Mean degree of moisture.

The least observed degree of moisture.

The maximum and minimum of temperature, both of the atmosphere and of radiation.

The direction of the wind, showing the number of days it blows from particular quarters."

In the same volume, page 102, commences the Journal of Observations for the year 1826, prefixed by some remarks by Mr. W. B. Booth, the principal clerk in the Garden, by whom the observations were made. From these remarks we learn that the first, or morning observation, was taken at six o'clock in the morning in summer, and at day-break in winter; the second near mid-day, that is, between noon and one o'clock, P.M.; and the third usually about nine, or between nine and ten o'clock at night, but not later.

The Meteorological Journal has been continued regularly down to the present time. In June, 1830,

Mr. Robert Thompson, under gardener in the fruit department, succeeded Mr. Booth as observer, but no alteration was made in the plan of the Journal.]

I shall proceed, first, to consider the general characters of the climate, as derivable from the averages of the seventeen years together; and I shall then endeavour to institute a comparison of the separate months with the mean, and with each other.

The mean pressure of the total atmosphere, denoted by the barometer, I find to be 29·931 inches. The mean of twenty years, deduced by Mr. Howard from the observations of the Royal Society, is 29·8655 inches. The mean temperature derived from the daily *maxima* and *minima* of the thermometer, is 49°·94, which differs little from Mr. Howard's estimate, which is 49°·5. The mean dew-point from the register appears to be 44°·31*. The elastic force of the vapour is ·342 inch, and a cubic foot of air contains 3·806 grains of moisture. The degree of dryness, calculated from the mean difference of the dew-point and the temperature of the air when the observation was made, is represented by 5°·59 upon the thermometric scale, and the degree of moisture by 827 upon the hygrometric scale. The average quantity of rain is 24·16 inches, and the amount of evaporation, calculated from the hygrometer, 28·598 inches. The weight of water, raised from a circular surface of six inches diameter, is 0·34 grain per minute.

* See note on the calculation of the dew-point, p. 318.

The entire range of the barometer is from 30·856 inches to 28·597 inches, mean being 1·815 inches; the range of the dew-point from 79° to 0°. The pressure of the vapour varies with it from ·973 inch to ·051 inch. The maximum temperarature of the air is 94°·40, the minimum $-4°·5$. The force of radiation from the sun averages 11°·8 in the day, and the force of radiation from the earth at night 4°·5; the highest temperature of the sun's rays is 130°, and the lowest temperature of the radiating thermometer is $-12°$. The greatest degree of dryness is 49°, or the least degree of moisture upon the hygrometric scale 235. The time of the day influences in some degree all the mean results. One of the most constant effects is that produced upon the barometer. The mercurial column reaches its maximum height in the morning, declines to its minimum in the afternoon, and again rises at night*. The means of the monthly observations present but one or two exceptions to the fall in the middle of the day, or to the rise from afternoon to night, but the rise from night to morning is not quite as constant.

With respect to the dew-point, it may be considered that the register includes four daily observations; for the observation of the minimum temperature of the air, which constantly falls a few degrees below

* The average difference of these periods, as exhibited by observations in the years 1819, 1820, and 1821, are as follow:—Morning above night, $+·005$ inch. Afternoon below morning, $-·015$ inch. Night above the afternoon, $+·010$ inch.

the term of precipitation taken in the day, must obviously be included* †.

* From observations made during the years 1819, 1820, and 1821, it appears that, from morning to afternoon the dew-point rises but 0·3 of a degree; from afternoon to night, it falls 0·9 of a degree; and below this again, the minimum temperature is 2°·7; and the mean is calculated from the latter, and the afternoon observation.

† [Unfortunately this fourth observation, viz., that of the lowest temperature of the shade thermometer, has in calculating the means been omitted; the mean dew-point given in the register is therefore actually the mean of the three observations made in the morning, noon, and evening only; and it is therefore higher than it ought to be. The Editors were unwilling to mutilate the tables as left by Professor Daniell, but in order to render the Essay as complete and accurate as possible, they have re-calculated the dew-points from the mean minimum shade observation, and the mean dew-point of each month as given in the tables. They have also deduced from this corrected dew-point the average daily greatest dryness, by deducting the mean day dew-point for each month from the mean maximum shade temperature for the same period, as well as the average daily dryness by deducting the corrected monthly mean dew-point from the recorded mean temperature of the corresponding periods; from these data they have also calculated the mean force of the vapour, mean saturation, mean daily least saturation, and mean amount of evaporation for each of the twelve months. In a synoptic table of the monthly means which they have subjoined to the tables, calculated by Professor Daniell from the registers of the Horticultural Society, the seven columns thus recalculated are substituted for the means given in the preceding tables, and each of the corrected columns is distinguished by an asterisk. These corrected numbers are employed in the Essay throughout. In all other cases the tables of the register are strictly adhered to. It is satisfactory to find a very general accordance of these dew-points for seventeen years with those deduced by the Author from the three years of his own ob-

The temperature of the air varies in the twenty-four hours from 58°·46, its mean maximum, to 41°·28, its mean minimum. The mean temperature of a climate is generally regarded as made up of the average impression of the sun due to its latitude upon the surface of the globe. The mean quantity of aqueous vapour must also be referable, finally, to the same principle. But there is another way of considering the subject more accurate in detail, though upon an average of years ending in the same conclusion; that is, to regard the mean temperature as made up of the temperature of different currents flowing from different points of the compass; and it will be necessary to my purpose to contemplate the atmosphere of vapour particularly in this point of view. The medium dew-point 44°·5 is therefore made up of the following proportions of the means from eight points of the wind:—

[87 North 40°·1 – 133 North-east 40°·7.
80 East 42°·3 – 111 South-east 45°·6.
70 South 48°·7 – 225 South-west 48°·6.
215 West 44°·8 – 174 North-west 41°·3.
Calculated by the Author from his own observations.]

Before I enter upon the consideration of the effect of the sun's progress in declination, and the succession

servations, the mean of the whole being, in the latter case 44°·5. The amount of evaporation is calculated according to the directions at pp. 29, 30 of the present volume, and must, therefore, only be looked upon, for reasons there detailed, as merely an approximation, though a pretty close one.]

of the seasons, I shall endeavour to point out the influence of the geographical situation of the island of Great Britain upon its aqueous atmosphere. The mean quantity of the vapour follows exactly the changes of the mean monthly temperature, that is to say, the dew-point rises and falls with the increase and the decrease of the heat. But the winds which transport the vapour may be divided into two classes; namely, the land winds which blow from off the great continent of Europe, and which comprise the north-east, the east, and south-east; and the sea winds which blow from the great oceans which surround it on every other side; namely, the north, north-west, west, south-west, and south. In the former, we may expect to find that the course of the mean temperature is exactly followed; for the sources of the vapour must be comparatively shallow streams, and reservoirs of water, whose temperature must soon adapt itself to that of the surrounding air. But in the unfathomable depths which supply the latter, the law by which the density of water is regulated, must, at particular seasons, maintain a temperature above the mean of the declining season; whilst at others, the increasing heat of the latter must outstrip the progress of the former. The following Table contains the dew-point of the several winds, divided into the two classes for every month in the year, beginning with the autumnal quarter.

[Table XLII. *Showing the difference of the Dew-point in the Land and Sea Winds.*

	Land Winds. N.E. E. S.E.	Sea Winds. N. N.W. W. S.W.
September	53°	53°
October	45	46
November	41	42
December	31	37
January	29	35
February	31	35
March	34	38
April	45	42
May	47	44
June	54	54
July	52	55
August	56	57

Calculated by the Author from his own observations during three years.]

And here the effect anticipated is clearly perceptible. The vapour of the land winds, it will be seen, declines in force from September to January, in which month it reaches its minimum, and from that point gradually rises till it reaches its maximum in August; and this, it will be afterwards seen, is the exact progress of the mean temperature of the air. In the sea winds the vapour follows the same course from September to November, and the balance is such, that the elastic force of both divisions is nearly the same. The north and south winds neutralize each other, and the north-west, west, and south-west, are equivalent to the north-east, east, and south-east. Having descended to about 40°, which is about the point of the greatest

density in water, in November, the accordance proceeds no further. In December, the vapour from the land has descended 6° below that from the sea, and the difference continues in January. In February the former rises 5°, and the latter remains stationary. The difference of 4° continues through March, and is diminished to 3° in April and May. In June they again attain their former equality. The reason of this is obvious; the temperature of 40°, being that of the greatest density, cannot be lowered till the whole mass of the waters has passed this term; and in the deep seas, this must necessarily be a process of some duration. The shallow waters, on the contrary, soon assume the temperature of the ambient air, and continue to decline with it in heat. Upon the return of spring the contrary effect is produced. The great deeps must again repass the fortieth degree before the superficial waters can take the higher temperature of the incumbent atmosphere. The consequences we should expect from this progression would be, an increase of humidity in December and January, and a rapid decrease in the four following months; an expectation which we shall find correct in our further investigation.

There is another law of the aqueous fluid, which we might also expect to have an influence upon the emission of its steam—the evolution, namely, of heat in the process of congelation and its absorption during the liquefaction of ice. The British isles are placed in such a position, as would induce us to suppose that, at particular seasons of the year, this influence might be

perceptible in one direction more than in any other. We may bring this idea to the test, by comparing together the northerly and southerly winds, as is done in the following Table :—

[TABLE XLIII. *Showing the Effect of the Ice in the North Seas upon the Dew-point.*

	Southerly. SW. S. SE.	Northerly. NE. N. NW.
September . .	58°	48°
October . . .	51	41
November . .	47	37
December . .	42	32
January . . .	38	31
February . . .	36	31
March	42	32
April	47	40
May	51	41
June	58	50
July	58	50
August	60	54

Calculated by the Author from his own observations during three years.]

Here we may observe, that the decline of the vapour from September to December, is exactly equal in both classes, but from that time it ceases about the temperature of 32° in the northerly winds, and continues in the southerly to the month of February. In March, again, the temperature of the southerly has increased from the minimum 6°, but in the former it still remains at 32°. In April, on the contrary, the northerly winds are much more frequent than the southerly; and in May, they have again attained their

original relative distances, and resume a progression nearly parallel. It would be difficult, I think, to assign any other cause for this modification of the phenomena than the one which has just been suggested. The evolution of heat, in the process of freezing, stops the decline of temperature in the regions exposed to its influence, while it proceeds in those which are not exposed to the change; and the absorption of heat, in the operation of thawing, prevents the accession of temperature, which is due to the returning influence of the sun. When this operation has ceased, the vapour quickly attains its former relative degree of force.

Wonderful adjustments these, to mitigate the rigours of a northern climate! They both operate from November to February, by the evolution of heat in the coldest season of the year; and at the same time, by an extra supply of vapour, decrease the degree of dryness, and prevent the consumption of heat which always attends the process of evaporation.

Let us now endeavour to trace the order from which, "while the earth remaineth, seed-time and harvest, and cold and heat, and summer and winter, and day and night, shall not cease."

In the month of January, the first month of the year, but which, in the most natural division of the seasons, constitutes the second month of the winter quarter, heat is at its minimum in all its particulars. The mean temperature is 36°·02, varying from 41°·1, the mean highest, to 30°·99, the mean lowest; the utmost range of the thermometer being from 60° to –4°5. The average power of the sun is 3°·68, and the

utmost intensity of its rays 16°. The cold, produced by radiation from the earth, is 4°·5, and the greatest effect 12°.

The mean force of the vaporous atmosphere is also at its lowest point, 0·228 inch, the dew-point being 33°·49. The mean degree of dryness, calculated from the difference between the mean temperature of the air and that of the dew-point, is 2°·53, and the state of the air's saturation 919. The average degree of greatest daily dryness is 5°·1, and that of least saturation 849.

The quantity of rain in this month greatly exceeds the amount of evaporation, the former being 1·56 inch, and the latter, at its minimum, 0·620 inch.

The height of the barometer is 29·952, and its mean range 1·438 inch, the greatest of any month in the year.

In the month of February the mean temperature increases to 39°·75, nearly 4°; the mean maximum temperature rises to 45°·94, nearly 5°, while the minimum advances to 33°·67; the temperature of the radiant thermometer averaging 28°·59, 2°·19 higher than in January. The greatest force of radiation is slightly diminished, being only 11°·70, but the average effect is increased to 5°·08.

The power of the sun rises to 6°·42, and its greatest intensity to 18°. The range of the diurnal temperature of the air is from 65° to 10°.

The dew-point advances to 35°·98, only 1°·5; the peculiar laws of the evaporating fluid keeping it back, as before explained. The force of the vapour is 0·248

inch. The consequence of this retardation is, that the mean degree of dryness advances to 3°·77, and the hygrometric state of the air falls to 892. The average degree of greatest dryness is 7°·44, and that of least saturation 758.

The quantity of rain is diminished, being 1·45 inch, and the amount carried off by evaporation increases to 0·840 inch.

The mean pressure of the atmosphere is 29·926 inches, and the range of the barometer 1·36 inch.

With the month of March commences the spring quarter, the seed-time of the husbandman, when it is so important to the interests of agriculture that the superfluous moisture should be exhaled from the earth, which would prevent the proper preparation of the soil, and destroy the germinating principle of the grain. By a wise Providence, therefore, the temperature of this month advances 3°·21, while the dew-point rises only 1°·84, checked by the same cause which began to restrain it in the last month. The mean temperature is 42°·96, and the point of precipitation 37°·82; making the degree of dryness 5°·14, and reducing the moisture of the air to 832. The elasticity of the vapour is ·263 inch. The evaporation is nearly doubled, amounting to 1·643 inch, and exceeding the quantity of rain, which is at its minimum, 1·36 inch. The average degree of greatest dryness is 10°·63, and that of least saturation 704.

It is during the day that the heat accumulates most, the maximum rising to 50°·86, and the minimum to 35°·41, an increase of nearly 5° in the former, and

only 1°·74 in the latter. The temperature of the air ranges from 75° to 19°. The amount of radiation is 5°·28, an increase of only two-tenths of a degree, and its maximum effect is 13°. The greatest force of the sun's direct rays is 28°, and their mean maximum effect 9°·98.

The height of the barometer is 29·935, and its range 1·209 inch

In April, the mean temperature of the air rises 4½° to 47°·57, and the constituent temperature of the vapour only 2°·75 to 40°·57, making the amount of dryness 7°·00. The degree of moisture is consequently no more than 773. The mean of maximum dryness 13°·74, and the mean of minimum saturation 627. The elasticity of the vapour ·286 inch. Evaporation is increased to 2·520 inches, and the quantity of rain does not exceed 1·55 inch. The power of radiation from the earth is raised to 12°·10, and its mean effect of 5°·51 approaches its highest amount. The power of the sun averages 11°·31, and the highest observed effect is 27°. The heat of the air ranges between 78° and 16°; the mean maximum being 57°·14, and the mean minimum 37°·75.

The mean height of the barometer for this month is 29·919 inches, and its average range 1·099 inch.

In May, the temperature of the air still outstrips the advance of the vapour, and the atmosphere attains its state of greatest dryness. The mean of the former is 55°·26, that of the latter 46°·79. The state of saturation 752, the degree of dryness 8°·47, the mean minimum of the former 590, the mean

maximum of the latter 15°·99. Elastic force of the vapour ·361 inch. Evaporation amounts to 3·999 inches, and rain to 1·67 inch. The power of the sun is 40°, its mean greatest influence 17°·18. The force of radiation, from the surface of the earth, is 12°; its nightly effect, now at its maximum, is 5°·59. The increase of this effect implies a rather less clouded state of the atmosphere than that of the preceding month. The mean maximum of the air is 66°·02, the mean minimum 43°·56: the range of the thermometer from 86° to 26°.

The height of the barometer is 29·959, its range 0·952 inch.

In June, the first month of the summer quarter, the advance of the dew-point is rather more rapid than that of the daily temperature: the former averages 53°·16, the latter 60°·68. The degree of dryness is 7°·72, and the state of the air's saturation 763.

The force of the vapour ·446 inch.

The quantity of evaporation falls a little short of that of the last month, and amounts to 3·750, and the quantity of rain is 1·980 inch.

The energy of the sun's beams continues to increase, though its maximum effect is a little less; the former amounts to 18°·60, and the mean of the latter 38°. The temperature of the air does not attain its maximum till the two following months. This arrangement must have an extremely important influence upon the fructification of the vegetable kingdom, and the horticulturist and botanist would do well to attend more particularly, than has hitherto been done, to the

different modifications of heat of radiation and heat of temperature. Experience has suggested many practical precautions and artifices evidently connected with this subject, and it is almost certain that a scientific attention to these particulars would tend much to the benefit of the art of gardening.

The force of radiation from the earth, I have once observed in this month to be 17°, the greatest effect that has ever come under my notice: its mean amount is 4°·95.

As connected with the subject to which I have alluded above, it is worth while to notice that there is not a single month in the year, in which vegetation, in particular situations, is not exposed to a temperature below the freezing point. The two hottest months are July and August, and even in them the radiant thermometer descends to 31°·10 and 29°*. Thus, a plant might be so situated, in the month of July, as to undergo all the changes of heat from 130° to 31°·10.

The mean maximum dryness of the month is 15°·26; the mean minimum saturation 614. The maximum temperature of the air averages 71°·69, the minimum 49°·89. The range of the thermometer is from 93° to 35°. The mean pressure is 29·970 inches, and the mean variation 0·84 inch.

In July, the increase of vapour is rather greater than that of temperature, and both attain their

* [These results, from a more extended series of observations, differ slightly from those quoted at p. 228.]

maximum. The mean heat of the air is 63°·17, and that of the dew-point 55°·37. The force of the vapour ·482 inch. The degree of dryness is 7°·80; the hygrometric degree 779. Mean maximum dryness of the day 15°·29. Mean minimum moisture 613. Evaporation advances to 4·247 inches, and the rain attains the quantity of 2·44 inches.

The increase of the mean temperature here appears to be principally derived from the night, for the mean maximum is only 74°·09, while the mean minimum has risen to 51°·95. This must be owing to the cooling power having been checked by a cloudy sky, and accordingly we find that the effect of radiation has fallen to 4°·18, while its greatest power is 10°.

The force of the sun's rays increases to 40°, and this is probably their utmost power, as the following month exhibits a slight decrease. Their average greatest effect is at the highest, and amounts to 19°·42. Mr. Howard's explanation of the mean temperature always being about a month behind the sun's place in declination, is, no doubt, as correct as it is ingenious; namely, that "as the sun advances in north declination, the heat we derive from him increases, actually in proportion to his altitude, but not sensibly; because a part of it is required to heat the earth, and is lost there by absorption. As he declines southward in the autumn, the heat we receive actually grows less in proportion, but not sensibly; because we now receive back a certain quantity from the warm earth."

The greatest range of the temperature of the air for this month is from 94°·40 to 37°·40.

The height of the barometer is 29·952 inches, and the mean range ·808 inch, the least in any month in the year.

The particulars of the month of August remain much the same as those of the month of July. The warm nights continue, and the heat of the day is undiminished. The mean temperature is 62°·78; the maximum of the day, 73°·58; and the minimum of the night, 51°·72. The range of the thermometer from 93° to 36°. The force of the sun's rays 37°; and their average maximum effect 18°. The power of radiation from the earth 10°, and its mean amount 4°·84.

The dew-point is 55°·16, and the elastic force of the vapour ·479. The degree of dryness 7°·62, and the state of saturation 786. Mean maximum dryness 14°·98; mean minimum moisture 631.

Evaporation is nearly the same as in the last month, amounting to 4·030 inches, but the rain is slightly decreased; the amount being 2·37 inches.

Mean height of the barometer 29·971 inches; mean range ·943 inch.

In September, the first month of Autumn, the reduction of temperature begins to be sensibly felt; but, still, less in the night than during the day. The mean temperature declines to 57°; the maximum to 67°·05, and the minimum to 47°·17; the greatest range of the thermometer being between 82° and 29°.

The mean dew-point is 50°·49, and the elasticity of the vapour ·407 inches; the dryness of the air 6°·51, and its state of saturation 801. Mean maximum dry-

ness 14°·24; and mean minimum moisture 652. The precipitation and evaporation are again nearly upon a par; the former attains its maximum, and averages 2·97 inches, the latter 3·030 inches. The power of the sun is considerably decreased, having fallen to 30°·6, and its mean daily amount 16°·11. Terrestrial radiation is also diminished, falling to 9°, and averaging 4°·23. The height of the barometer is 29·882 inches, and its mean range 1·067 inch.

In October, the mean temperature falls nearly 7°, and does not exceed 50°·37; the maximum and minimum averaging, respectively, 59°·16 and 41°·99. The dew-point declines less rapidly, falling only to 45°·64. The dryness is reduced to 4°·73, and moisture increases to 830. The average daily greatest dryness is 9°·85, and the mean minimum saturation 710. Evaporation decreases to 2·139 inch, while the rain continues very considerable, the amount for the month being 2·46 inches. Now that the fruits of the earth are laid up in store, this large amount of wet is attended with no injurious effects; the remaining heat of the earth is preserved from a needless expenditure, and guarded from dissipation by an increasing canopy of clouds. The effect of radiation is reduced to 4°·63, and its greatest force to 9°. The power of the solar rays declines to 36°, and their mean effect to 12°·10. The greatest range of the air's temperature is from 80° to 20°. The mean elasticity of the vapour is ·336 inch, the pressure of the whole atmosphere 29·949 inches, and the average range of the barometer 1·273 inch.

In the dark and dreary month of November, the atmosphere is nearly saturated with moisture. The temperature of the air is 43°·12, and the dew-point averages no lower than 39°·87; the dryness is only 3°·25, and the dampness amounts to 878. The precipitations are augmented to 2·58 inches, and only 1·170 inch is carried off by evaporation. The maximum dryness of the days is but 7°·62, and the least degree of moisture 773. The effect of the sun's rays, whose greatest power is 19°, is scarcely 6°·3, and that of terrestrial radiation only 4°·14, its intensity being 10°.

The mean highest point of daily temperature is 50°·44, and the mean lowest 36°·93; the utmost range of the thermometer being from 63° to 15°.

The mean elasticity of the vapour is ·279 inch; the pressure of the whole atmosphere, 29·834 inches, and the range of the barometer 1·377 inch.

The month of December closes the year with nearly the same characters as those of the last month; mean temperature, 40°·09; mean maximum, 45°·47; mean minimum, 34°·96; greatest range, from 61° to 10°.

The greatest force of the sun's rays is 13°, their mean influence, 3°·48; power of terrestrial radiation, 9°; mean effect, 4·13.

Temperature of the dew-point, 37°·47; degree of dryness, 2°·62; and state of saturation, 928; mean maximum dryness, 5°·46; mean minimum moisture, 810.

Amount of precipitation, 1·65 inches; of evaporation, 0·620 inch.

The elasticity of the vapour, ·260 inch; pressure of the atmosphere, 29·957 inches, and range of the barometer, 1·281 inch.

I have not, in the preceding summary, noticed the prevalent winds of the several months, or distinguished the quality of the vapour transported from the different quarters of the compass. I have thought it better to separate this view of the subject from the preceding, and to present the results in a tabular form. The following Table exhibits the average number of days on which the different winds blow in each month of the year, together with the mean dew-point of the vapour which is wafted by them:—

[TABLE XLIV. *Shewing the Dew-Point of Eight different Winds in each Month, and the average Number of Days on which each prevails.*

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
	No. of Days. Dew-Point.	No. of Days. Dew-Point.	No. of Days. Dew-Point.	No. of Days. Dew-Point.	No. of Days. Dew-Point.	No. of Days. Dew-Point.	No. of Days. Dew-Point.	No. of Days. Dew-Point.
January	3½ — 31°·5	4½ — 27°·5	1½ — 23°·5	2¼ — 34°·5	1¾ — 39°	6½ — 42°·5	6¼ — 37°	4½ — 32°
February........	1¼ — 30·0	4¾ — 29	2½ — 32	2¾ — 34·5	2¼ — 37·5	5 — 39·5	5½ — 39	3¾ — 34
March	2½ — 31·5	4 — 31	....	2 — 35·0	2¼ — 47·0	9½ — 44·5	6¼ — 42	4½ — 35
April	2½ — 40	3¼ — 40·5	3 — 45	3½ — 49·0	2¾ — 47	4 — 45	5½ — 44	5½ — 42
May	3 — 42	4 — 40·5	4½ — 45·5	4 — 50·5	1 — 54	6¼ — 49·5	5¼ — 46·5	3 — 41
June	5 — 49·5	6½ — 49·5	2 — 56	4 — 57	1 — 62	3½ — 56	3 — 52	5 — 50·5
July	2½ — 50	3 — 49	2 — 50·5	4 — 58	2¼ — 58·5	7 — 59	5 — 56	5¼ — 53
August	1 — 55·5	2¾ — 53	1½ — 55·5	3 — 60	2¼ — 63·0	6 — 58·5	11½ — 55	3 — 53
September	2 — 45	4 — 50	1 — 52	4 — 56	1 — 61	6 — 58	6 — 54	6 — 49·5
October	3 — 38·5	3¼ — 41·5	2 — 45·5	3½ — 49	2¼ — 53·5	5¾ — 50·5	5 — 46·5	6¼ — 43
November	2 — 38·0	3 — 37	3 — 40	2 — 46	3 — 48·0	6 — 47·5	5 — 42	5 — 35·5
December	1 — 31·5	2¼ — 29	3½ — 27·5	4 — 38	2 — 45·5	8¼ — 44	6 — 40	4 — 35
	30½ — 40	45¼ — 39·5	26½ — 43	39 — 47	23¾ — 51	73¾ — 49	70¼ — 47	55¾ — 42

Table calculated by the Author from his own observations during three years.]

This Table is constructed from the observations of the morning, afternoon, and night, leaving out those of the minimum temperature; and therefore the total means differ slightly from those already given. This has been done for the sake of forming a standard of comparison, whereby to judge of the state of the weather from hygrometric observations. The mean monthly temperature of the dew-point affords a useful criterion for this purpose, but the average state of each wind is much more accurate; and when the Table shall have been improved by the results of a longer series of experiments, an almost infallible judgment may be formed from it of the probability of atmospheric changes.

It will be observed in the Table, that the northerly winds and the southerly are in nearly equal proportions, but that the westerly are to the easterly nearly as two to one. These proportions are preserved in the several quarters of the year.

It is also worthy of remark, that the dew-point of the sea winds, viz., the S.W. W. and N.W. is 3° higher than that of the land winds from the opposite quarters, viz., N.E. E. and S.E.

ABSTRACTS

OF

METEOROLOGICAL OBSERVATIONS,

COMPILED FROM THE REGISTER KEPT AT THE GARDENS OF THE HORTICULTURAL SOCIETY, AT CHISWICK, DURING A PERIOD OF SEVENTEEN YEARS,

FROM 1826 TO 1842, INCLUSIVE.

Date.	TEMPERATURE.								
	Mean Shade.	Max. Shade.	Max. Sun.	Diff.	Mean Max. Shade.	Mean Max. Sun.	Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
1826	51·83	93	116	23	58·37	72·20	14·8	11	3
1827	49·70	89	118	29	58·59	72·93	14·3	12	4
1828	51·63	85	107	22	59·68	71·82	12·1	21	13
1829	47·80	84	110	26	55·71	68·06	12·4	15	5
1830	49·30	88	117	29	57·67	71·54	13·9	10	4
1831	51·60	86	117	31	60·52	73·68	13·1	13	5
1832	50·80	85	110	25	58·56	73·22	14·7	22	14
1833	50·90	87	126	39	59·56	75·82	16·3	22	12
1834	52·00	94	130	36	61·27	76·77	15·5	24	15
1835	50·40	92·3	120	27·7	59·75	69·87	10·1	16·2	8·6
1836	49·38	94·4	128·3	33·9	57·70	68·10	10·4	13·1	7·7
1837	48·52	86·9	113·9	27	57·39	65·91	8·5	12·2	10
1838	47·67	84	107	23	56·47	63·53	7·1	—4·5	—12
1839	49·61	85	110	25	57·67	68·24	10·6	17	9
1840	48·78	87	108	21	57·95	68·71	10·8	12	1
1841	49·32	84	104	20	57·89	64·23	6·3	·6	1
1842	49·80	93	120	27	59·16	69·70	10·6	18	11
Means ..	49·94				58·46	70·25			
Extremes	52·00 47·67	94·4	130	36	61·27 55·71	76·77 63·53	16·3	—4·5	—12

Date.	BAROMETER.				FORCE OF VAPOUR.		
	Mean.	Highest.	Lowest.	Range.	Mean.	Highest.	Lowest.
1826	30·065	30·650	28·752	1·898	·383	·723	·081
1827	29·900	30·729	28·881	1·848	·378	·748	·088
1828	29·921	30·594	28·997	1·597	·400	·799	·136
1829	29·932	30·665	28·978	1·687	·350	·723	·103
1830	29·914	30·787	28·720	2·067	·378	·973	·084
1831	29·900	30·665	28·943	1·722	·411	·799	·121
1832	30·007	30·591	29·156	1·435	·396	·773	·136
1833	29·905	30·783	28·910	1·873	·382	·699	·126
1834	30·055	30·674	29·071	1·603	·382	·799	·112
1835	29·981	30·856	28·851	2·005	·379	·826	·107
1836	29·886	30·733	28·655	2·078	·367	·799	·095
1837	29·958	30·713	28·801	1·912	·370	·854	·078
1838	29·882	30·601	28·673	1·928	·355	·773	·051
1839	29·896	30·573	28·978	1·595	·379	·826	·092
1840	29·927	30·726	28·597	2·129	·350	·699	·099
1841	29·785	30·512	28·808	1·704	·347	·799	·081
1842	29·924	30·582	28·703	1·879	·387	·854	·107
Means ..	29·931			1·815	·376		
Extremes	30·065 29·785	30·856	28·597	2·129 1·435	·411 ·347	·973	·051

TEMPERATURE.				DEW-POINT.					Date.
Diff.	Mean Min. Shade.	Mean Min. Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	
°	°	°	°	°	°	°	°	°	
8	43·78	37·26	6·5	47·48	70	11	4·21	29	1826
8	42·06	36·36	5·7	47·70	71	13	4	27	1827
8	43·59	38·21	5·3	49·80	73	24	3	24	1828
10	40·01	34·33	5·7	45·25	70	17	2·637	25	1829
6	41·19	35·61	5·5	47·00	79	12	3·43	24	1830
8	43·47	38·28	5·2	49·80	73	21	2·9	28	1831
8	41·25	36·11	5·1	48·10	72	24	2·69	28	1832
10	40·98	36·16	4·8	47·70	69	22	3·14	30	1833
9	42·90	38·52	4·4	48·40	73	19	4·16	35	1834
7·6	40·09	37·10	2·9	47·50	74	18	3·56	32	1835
5·4	41·03	35·94	2·1	46·59	73	15·5	3·09	35	1836
2·2	39·67	35·66	4·0	46·42	75	10·5	3·06	38	1837
7·5	39·38	35·44	3·9	45·07	72	0	3·32	43	1838
8	41·61	37·26	4·4	47·38	74	14	4·12	31	1839
11	39·59	34·70	4·8	45·23	69	16	4·48	37	1840
5	40·71	37·52	3·2	47·88	73	11	2·48	28	1841
7	40·49	36·43	4·0	47·86	75	18	3·46		1842
	41·28	36·52		47·36			3·309		Means
11	43·78 39·38	38·52 34·33	6·5	49·80 45·07	79	0	4·48 2·48	43	Extremes

SATURATION.			WINDS. No. of Days in the Year during which each Wind prevails.								Date.
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	
876	377	21·83	19	55	27	37	44	65	68	61	1826
874	414	22·18	24	32	30	38	53	71	66	51	1827
905	457	27·85	18	35	44	30	52	82	68	36	1828
799	441	26·12	28	75	56	20	41	58	46	40	1829
878	457	24·27	20	36	46	21	50	79	90	23	1830
909	391	26·93	24	33	49	11	75	83	71	19	1831
916	382	21·59	30	40	45	25	63	68	72	23	1832
903	377	25·80	25	50	33	16	57	78	86	20	1833
867	320	20·39	18	48	40	22	77	86	56	18	1834
886	356	23·17	33	30	28	21	67	96	66	24	1835
905	310	28·73	21	38	26	13	62	126	57	23	1836
907	273	19·88	35	59	30	17	64	67	52	31	1837
894	235	21·57	38	61	34	27	48	72	47	38	1838
904	346	28·30	17	51	35	29	64	79	54	36	1839
833	324	18·87	29	46	47	11	38	78	84	33	1840
915	373	30·97	17	48	17	18	59	96	75	35	1841
899	427	22·31	20	67	44	15	53	74	63	29	1842
886	368	24·16	24·4	47·2	37·1	21·8	56·8	79·8	65·8	31·7	Means
916 799	235	30·97 18·87	38 17	75 30	56 17	38 11	77 38	126 58	90 46	61 18	Extremes

Date.	TEMPERATURE. Mean Shade.	Max. Shade.	Max. Sun.	Diff.	Mean Max. Shade.	Mean Max. Sun.	Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
1826	32·80	48	63	15	37·10	44·60	7·50	11	3
1827	32·50	53	62	9	40·70	47·30	6·60	12	5
1828	40·50	60	70	10	46·00	50·90	6·60	24	15
1829	32·80	49	63	14	37·50	43·50	6·00	17	9
1830	31·70	45	52	7	36·00	39·12	3·12	10	7
1831	35·50	50	66	16	39·93	45·83	5·90	20	8
1832	37·20	51	60	9	42·22	47·51	5·29	22	15
1833	35·50	47	59	12	39·29	42·42	3·13	22	12
1834	45·40	58	62	4	50·29	53·09	2·80	28	18
1835	39·70	52·7	59	6·3	44·67	46·92	2·25	18·9	14·9
1836	38·96	54·5	55·4	0·9	44·17	45·19	1·02	13·1	7·7
1837	38·50	50·9	51·8	0·9	43·28	43·70	0·42	12·2	7·3
1838	27·79	49	55	6	32·87	33·55	0·68	—4·5	—12
1839	37·85	53	59	6	44·66	49·90	5·84	17	11
1840	39·24	55	56	1	45·57	48·80	3·23	12	1
1841	34·25	53	56	3	39·90	41·11	1·21	6	1
1842	32·45	47	50	3	37·81	38·87	1·06	18	11
Means . .	36·02				41·1	44·7	3·68		
Extremes	45·40 27·79	60	70	16	50·29 32·87	53·09 33·55	7·50 0·42	—4·5	—12

Date.	BAROMETER. Mean.	Highest.	Lowest.	Range.	FORCE OF VAPOUR. Mean.	Highest.	Lowest.
1826	30·110	30·650	29·499	1·151	·208	·313	·081
1827	29·911	30·403	29·226	1·177	·232	·389	·088
1828	29·974	30·507	29·200	1·307	·292	·432	·136
1829	29·822	30·405	29·088	1·317	·216	·302	·107
1830	30·043	30·787	28·720	2·067	·212	·251	·112
1831	29·885	30·665	29·151	1·514	·243	·349	·121
1832	30·011	30·509	29·379	1·130	·253	·361	·136
1833	30·242	30·783	29·443	1·340	·241	·336	·131
1834	29·755	30·449	29·071	1·376	·328	·447	·142
1835	30·109	30·856	29·081	1·775	·265	·389	·112
1836	29·968	30·733	28·978	1·755	·277	·389	·095
1837	29·956	30·585	29·344	1·241	·264	·389	·103
1838	29·927	30·447	29·328	1·119	·190	·336	·051
1839	29·916	30·573	29·039	1·534	·253	·361	·092
1840	29·828	30·588	28·742	1·846	·272	·402	·099
1841	29·772	30·505	28·864	1·641	·200	·375	·081
1842	29·969	30·452	29·100	1·352	·223	·336	·116
Means .	29·952			1·438	·245		
Extremes	30·242 29·755	30·856	28·720	2·067 1·119	·328 ·190	·447	·051

TEMPERATURE.				DEW-POINT.					Date.
Diff.	Mean Min. Shade.	Mean Min. Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	
°	°	°	°	°	°	°	°	°	
8	28·50	22·36	6·14	31·10	46	11	1·7	17	1826
7	29·20	24·20	5·00	34·70	52	13	1·8	11	1827
9	35·00	30·60	4·40	41·20	55	24	1·1	8	1828
8	28·10	22·80	5·30	32·00	45	18	1·5	7	1829
3	27·50	23·74	3·76	31·50	40	19	1·35	11	1830
12	31·09	27·09	4·00	35·40	49	21	0·67	8	1831
7	32·19	27·64	4·55	36·60	50	24	0·21	6	1832
10	31·29	25·80	5·49	35·10	48	23	0·34	5	1833
10	40·64	36·48	4·16	44·80	56	25	1·23	11	1834
4	32·79	29·03	3·76	38·10	52	19	0·88	8	1835
5·4	33·76	25·72	8·04	37·80	52	15·5	0·77	10	1836
4·9	34·00	30·50	3·50	38·00	52	17	0·17	8	1837
7·5	22·72	19·12	3·60	28·40	48	0	0·75	9	1838
6	31·64	27·26	4·38	36·89	50	14	1·08	11	1839
11	32·71	28·51	4·20	39·31	53	16	0·74	10	1840
5	28·61	24·35	4·26	34·58	51	11	0·61	9	1841
7	27·09	23·22	3·87	32 89	48	20	1·12		1842
	30·99	26·4	4·5	36			·94		Means
12	40·64 22·72	36·48 19·12	8·04 3·50	44·80 28·40	56	0	1·80 0·17	17	Extremes

SATURATION.			WINDS. No. of Days in the Month during which each Wind prevails.								Date.
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	
963	550	0·27	3	2	7	8	1	5	1	4	1826
935	685	0·57	5	4	2	0	2	6	3	9	1827
965	759	3·71	1	4	3	3	7	8	5	0	1828
964	787	0·30	4	11	8	2	1	1	1	3	1829
954	685	1·54	8	13	5	1	0	2	1	1	1830
979	758	1·02	4	6	6	3	8	1	3	0	1831
999	838	1·32	2	1	5	3	9	8	1	2	1832
992	843	0·52	1	11	8	3	3	4	1	0	1833
973	682	2·87	1	0	1	0	9	11	6	3	1834
970	677	0·72	2	2	2	4	3	10	6	2	1835
985	715	2·01	0	2	3	1	11	9	5	0	1836
995	842	3·03	4	2	3	1	7	8	5	1	1837
979	735	0·27	5	11	5	3	4	1	0	2	1838
962	676	1·27	1	3	0	1	1	5	10	10	1839
971	712	2·48	1	3	2	1	6	7	10	1	1840
976	708	2·60	5	2	2	3	1	6	7	5	1841
961	730	1·06	2	4	2	4	4	5	3	7	1842
972	728	1·56	2·8	4·7	3·7	2·4	4·5	5·7	4·0	2·9	Means
999 935	550	3·71 0·27	8 0	13 1	8 0	8 0	11 0	11 1	10 0	10 0	Extremes

Date.	TEMPERATURE.								
	Mean Shade.	Max. Shade.	Max. Sun.	Diff.	Mean Max. Shade.	Mean Max. Sun.	Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
1826	42·28	56	68	12	49·40	58·50	9·10	26	19
1827	36·00	57	71	14	40·20	49·90	9·70	15	4
1828	41·60	60	69	9	47·50	55·30	7·80	23	17
1829	39·70	52	70	18	45·10	53·20	8·10	15	5
1830	36·60	59	72	13	42·85	50·10	7·25	10	4
1831	42·50	65	80	15	49·50	59·42	9·92	13	5
1832	38·50	54	66	12	44·69	53·79	9·10	24	14
1833	43·70	56	65	9	49·75	55·00	5·25	29	20
1834	41·50	59	72	13	48·93	57·28	8·35	24	16
1835	43·20	56·3	59	2·7	50·00	53·60	3·60	23·9	18·9
1836	38·00	53·6	68·9	15·3	44·24	52·16	7·92	19·4	7·7
1837	41·20	55·4	58·1	2·7	47·76	49·44	1·68	26·6	17·6
1838	33·76	53	56	3	39·89	41·53	1·64	14	9
1839	40·40	53	71	18	47·14	55·67	8·53	20	14
1840	39·30	53	61	8	44·96	49·31	4·35	24	16
1841	36·60	56	62	6	41·42	44·14	2·72	14	8
1842	40·03	54	65	11	47·71	51·78	4·07	23	18
Means ..	39·75				45·94	52·36	6·42		
Extremes	43·70	65	80	18	50·00	59·42	9·92		
	33·76				39·89	41·53	1·64	10	4

Date.	BAROMETER.				FORCE OF VAPOUR.		
	Mean.	Highest.	Lowest.	Range.	Mean.	Highest.	Lowest.
1826	30·075	30·500	29·418	1·082	·304	·389	·165
1827	30·105	30·635	29·459	1·186	·200	·402	·103
1828	29·854	30·521	29·048	1·473	·292	·402	·147
1829	30·086	30·665	29·102	1·563	·264	·389	·107
1830	29·941	30·401	29·381	1·020	·236	·463	·084
1831	29·874	30·446	28·994	1·452	·299	·463	·153
1832	30·109	30·591	29·231	1·360	·262	·417	·153
1833	29·565	30·070	29·096	0·974	·314	·447	·186
1834	30·177	30·517	29·663	0·854	·280	·417	·142
1835	29·854	30·531	29·039	1·492	·265	·417	·142
1836	29·862	30·527	28·688	1·839	·247	·361	·131
1837	29·969	30·487	29·162	1·325	·277	·432	·142
1838	29·625	30·454	28·740	1·714	·222	·389	·103
1839	29·999	30·559	29·467	1·092	·272	·402	·121
1840	29·950	30·661	28·597	2·064	·257	·389	·116
1841	29·768	30·346	29·071	1·265	·213	·375	·088
1842	29·942	30·488	29·115	1·373	·288	·375	·159
Means ..	29·926			1·360	·264		
Extremes	30·177	30·665		2·064	·314	·463	
	29·565		28·597	0·854	·200		·084

TEMPERATURE.				DEW-POINT.					Date.
Diff.	Mean Min. Shade.	Mean Min. Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	
°	°	°	°	°	°	°	°	°	
7	42·00	32·80	9·20	42·20	52	29	2·08	12	1826
11	27·60	20·70	6·90	30·00	53	17	4·30	17	1827
6	35·70	30·70	5·00	41·10	53	26	1·50	9	1828
10	34·30	29·30	5·00	38·80	52	18	1·60	15	1829
6	30·35	24·89	5·46	34·50	57	12	2·64	10	1830
8	35·64	29·60	6·04	41·60	57	27	1·70	16	1831
10	32·48	28·24	4·24	37·80	54	27	0·67	10	1832
9	37·69	33·35	4·34	42·90	56	32	0·66	8	1833
8	34·06	28·47	6·59	40·00	54	25	1·40	14	1834
5·0	36·42	32·00	4·42	41·40	54	25	1·67	11	1835
11·7	31·88	24·89	6·99	36·00	50	23	1·91	14	1836
9·0	34·64	29·92	4·72	39·70	55·5	25	1·20	16	1837
5	27·64	24·78	2·86	32·79	52	17	1·56	14	1838
6	33·67	28·89	4·78	38·99	53	21	1·39	13	1839
8	33·65	28·72	4·93	37·21	52	20	2·13	12	1840
6	31·78	29·17	2·61	35·72	51	13	1·50	16	1841
5	32·96	29·71	3·25	40·69	51	28	1·07		1842
	33·67	28·59	5·08	38·31			1·70		Means
11·70	42·0	33·35	9·20	42·90	57		2·64	17	Extremes
	27·6	20·70	2·61	30·00		12	0·66		

SATURATION.			WINDS. No. of Days in the Month during which each Wind prevails.								Date.
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	
923	660	1·71	0	0	0	0	8	9	9	2	1826
862	550	0·79	8	3	8	2	3	0	2	2	1827
960	682	0·94	2	3	3	4	3	3	5	6	1828
943	607	1·07	1	2	6	4	1	4	5	5	1829
915	715	1·33	2	8	0	2	1	4	11	0	1830
934	574	2·27	1	1	3	0	6	6	10	1	1831
973	853	0·23	6	5	3	4	6	3	1	1	1832
975	756	3·98	3	2	2	0	5	9	7	0	1833
942	617	0·37	1	2	1	3	7	5	7	2	1834
970	677	0·72	2	2	2	4	3	10	6	2	1835
943	640	1·61	5	2	3	0	1	13	2	3	1836
955	578	2·01	2	1	1	3	8	8	4	1	1837
948	731	2·22	3	8	7	4	2	3	1	0	1838
957	634	2·19	1	3	0	2	2	6	11	3	1839
937	658	1·25	0	4	8	1	2	11	1	2	1840
942	583	0·76	1	11	3	2	5	3	1	2	1841
996	710	1·32	0	0	5	0	12	3	4	4	1842
945	660	1·45	2·2	3·3	3·2	2	4·4	5·8	5·1	2·1	Means
996		3·98	8	11	8	4	12	13	11	6	Extremes
862	550	0·23	0	0	0	0	1	0	1	0	

Date.	TEMPERATURE.								
	Mean Shade.	Max. Shade.	Max. Sun.	Diff.	Mean Max. Shade.	Mean Max. Sun.	Diff.	Min. Shade.	Min Rad.
	°	°	°	°	°	°	°	°	°
1826	43·40	68·00	88	20	47·00	65·00	18·00	26	13
1827	43·50	60·00	76	16	51·90	62·60	10·70	27	17
1828	40·50	67·00	95	28	53·00	69·00	16·00	24	13
1829	40·50	60·00	79	19	47·64	62·45	14·81	21	8
1830	48·30	75·00	97	22	57·22	69·54	12·32	31	21
1831	46·20	65·00	81	16	53·96	61·58	7·62	30	19
1832	42·50	57·00	84	27	50·11	64·29	14·18	25	15
1833	39·20	58·00	70	12	46·38	56·25	9·87	23	13
1834	45·00	60·00	81	21	53·38	67·54	14·16	24	15
1835	43·20	63·50	68·9	5·4	50·12	55·70	5·58	25·2	18·5
1836	45·10	69·00	87·2	18·2	52·19	58·26	6·07	25·7	13·6
1837	37·94	49·40	61·7	12·3	44·34	51·02	6·68	19·4	10·0
1838	42·16	62·00	68	6	51·45	54·58	3·13	24	18
1839	41·95	58·00	72	14	48·32	59·00	10·68	20	9
1840	39·70	56·00	66	10	48·06	54·61	6·55	19	12
1841	46·35	67·00	74	7	57·09	61·93	4·84	27	22
1842	44·98	60·00	75	15	52·48	61·03	8·55	26	21
Means..	42·96				50·86	60·84	9·98		
Extremes	48·30 37·94	75	97	28	57·22 44·34	69·00 51·02	18·00 3·13	19	8

Date.	BAROMETER.				FORCE OF VAPOUR.		
	Mean.	Highest.	Lowest.	Range.	Mean.	Highest.	Lowest.
1826	30·077	30·529	29·491	1·038	·272	·432	·131
1827	29·748	30·563	28·881	1·682	·304	·389	·165
1828	29·949	30·395	28·997	1·398	·292	·432	·136
1829	29·877	30·403	29·250	1·153	·256	·389	·142
1830	30·144	30·614	29·498	1·116	·318	·375	·186
1831	29·899	30·515	29·177	1·338	·335	·417	·179
1832	29·941	30·380	29·363	1·017	·282	·389	·172
1833	29·872	30·351	29·354	0·997	·248	·361	·126
1834	30·245	30·596	29·559	1·037	·224	·417	·142
1835	29·976	30·606	28·851	1·755	·290	·432	·131
1836	29·973	30·460	28·655	1·805	·315	·514	·179
1837	29·979	30·431	29·301	1·130	·233	·324	·092
1838	29·839	30·556	29·116	1·440	·274	·497	·159
1839	29·823	30·238	29·261	0·977	·271	·417	·131
1840	30·269	30·726	29·823	0·903	·235	·336	·121
1841	29·895	30·512	29·525	0·987	·295	·447	·193
1842	29·821	30·332	29·152	0·780	·327	·480	·186
Means..	29·935			1·209	·280		
Extremes	30·269 29·748	30·726	28·655	1·805 0·780	·335 ·233	·514	·092

TEMPERATURE.				DEW-POINT.					
Diff.	Mean Min. Shade.	Mean Min. Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	Date.
°	°	°	°	°	°	°	°	°	
13	35·00	28·00	7·00	39·50	55	23	3·90	20	1826
10	37·00	32·80	4·20	42·90	52	29	3·00	20	1827
11	37·00	30·00	7·00	41·00	55	24	4·10	17	1828
13	33·32	27·29	6·03	37·00	52	25	4·33	22	1829
10	39·45	33·22	6·23	43·30	51	32	5·26	23	1830
11	38·58	33·58	5·00	44·60	54	31	2·48	18	1831
10	34·93	28·90	6·03	40·20	52	30	2·78	28	1832
10	32·16	25·80	6·36	36·00	50	22	2·99	17	1833
9	36·80	31·19	5·61	40·70	54	25	4·81	26	1834
6·7	35·33	31·36	3·97	40·80	55·5	23	1·98	15	1835
12·1	38·06	32·28	5·78	42·90	60	31	1·58	15	1836
9·4	31·54	26·14	5·40	34·10	47	14	3·45	27	1837
6	32·87	29·71	3·16	39·30	59	28	3·39	21	1838
11	35·58	30·54	5·04	38·89	54	23	2·81	21	1839
7	31·35	25·74	5·61	34·42	48	21	4·57	29	1840
5	35·61	31·45	4·16	44·42	56	33	2·47	22	1841
5	37·48	34·29	3·19	43·98	58	32	2·31		1842
	35·41	30·13	5·28	40·23			3·30		Means
13	39·45	33·58	7·00	44·60	60		4·81	29	Extremes
	31·35	25·74	3·16	34·10		14	1·58		

SATURATION.			WINDS. No. of Days in the Month during which each Wind prevails.								
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Date.
860	500	1·62	6	5	0	4	2	4	6	4	1826
894	504	2·50	2	0	0	0	2	6	14	7	1827
858	358	0·59	4	2	1	4	1	6	7	6	1828
876	469	0·75	2	8	13	3	0	3	1	1	1829
836	472	0·18	0	4	5	2	5	9	4	2	1830
917	540	1·91	0	3	6	0	4	5	13	0	1831
892	382	1·50	2	5	2	3	8	2	6	3	1832
911	559	1·22	6	10	3	4	2	1	3	2	1833
855	397	0·86	1	4	5	1	3	8	6	3	1834
923	600	1·97	1	7	1	1	1	10	8	2	1835
943	609	3·30	0	0	1	0	8	17	4	1	1836
896	393	0·54	5	12	1	1	1	5	2	4	1837
878	504	0·86	3	4	3	2	5	5	4	5	1838
903	488	1·95	1	8	2	5	1	6	5	3	1839
864	369	0·28	7	10	6	0	1	0	3	4	1840
916	546	1·32	0	0	1	1	9	13	6	1	1841
921	636	1·81	3	0	0	1	3	11	10	3	1842
891	489	1·36	2·5	4·8	2·9	1·8	3·2	6·5	6·	3·	Means
943		3·30	7	12	13	5	9	17	14	7	Extremes
836	358	0·18	0	0	0	0	0	0	1	0	

Date.	TEMPERATURE.								
	Mean Shade.	Max. Shade.	Max. Sun.	Diff.	Mean Max. Shade.	Mean Max. Sun.	Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
1826	50·60	71	87	16	59·60	74·80	15·20	29	19
1827	51·50	78	105	27	58·50	73·20	15·70	25	17
1828	49·18	75	94	19	57·30	63·60	6·30	29	19
1829	46·00	61	82	21	53·70	66·66	12·96	29	19
1830	50·70	77	102	25	59·50	75·96	16·46	24	12
1831	51·40	69	83	14	60·60	69·63	9·03	31	23
1832	48·10	74	101	27	58·60	78·56	19·96	30	21
1833	47·20	67	81	14	57·06	66·96	9·96	29	20
1834	46·80	69	90	21	57·13	72·36	15·23	26	18
1835	48·40	73·4	81·5	8·1	59·59	66·43	6·84	25·7	19·4
1836	45·30	63·1	84·2	21·1	53·70	67·02	13·32	27·5	15·4
1837	41·95	63·5	70·4	7·9	50·28	57·84	7·56	23·6	14·0
1838	44·06	69	73	4·	53·33	57·76	4·43	16	8
1839	44·44	73	96	23	52·63	65·16	12·53	24	13
1840	49·83	81	99	18	64·80	75·96	11·16	25	16
1841	47·09	76	81	5	57·40	63·70	6·30	26	20
1842	46·28	75	98	23	57·70	67·06	9·36	23	17
Means ..	47·57				57·14	68·39	11·31		
Extremes	51·50 41·95	78	105	27	64·80 50·28	78·56 57·76	19·96 4·43	16	8

Date.	BAROMETER.				FORCE OF VAPOUR.		
	Mean.	Highest.	Lowest.	Range.	Mean.	Highest.	Lowest.
1826	30·099	30·445	29·523	0·922	·316	·514	·159
1827	30·013	30·386	29·540	0·846	·352	·570	·165
1828	29·799	30·383	29·229	1·154	·352	·590	·142
1829	29·673	30·158	28·978	1·180	·316	·447	·179
1830	29·796	30·283	29·246	1·037	·336	·514	·172
1831	29·733	30·470	29·209	1·261	·381	·532	·200
1832	30·015	30·578	29·170	1·408	·335	·432	·159
1833	29·765	30·285	28·910	1·375	·344	·480	·208
1834	30·178	30·515	29·305	1·210	·292	·532	·112
1835	30·138	30·499	29·558	0·941	·329	·497	·121
1836	29·872	30·412	29·034	1·378	·312	·417	·121
1837	29·811	30·376	29·424	0·952	·255	·432	·078
1838	29·807	30·287	29·200	1·087	·270	·480	·131
1839	30·094	30·550	29·409	1·141	·280	·417	·159
1840	30·076	30·416	29·480	0·936	·310	·432	·159
1841	29·839	30·171	29·371	0·800	·294	·699	·172
1842	30·022	30·355	29·303	1·052	·284	·514	·147
Means ..	29·919			1·099	·315		
Extremes	30·178 29·673	30·578	28·910	1·408 0·800	·381 ·255	·699	·078

TEMPERATURE.				DEW-POINT.					
Diff.	Mean Min. Shade.	Mean Min. Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	Date.
°	°	°	°	°	°	°	°	°	
10	42·10	35·40	6·70	43·90	60	28	6·90	29	1826
8	39·00	34·00	5·00	46·60	63	29	4·40	25	1827
10	41·06	35·26	5·80	46·70	64	25	4·14	20	1828
10	38·40	32·36	6·04	43·90	56	31	2·57	17	1829
12	41·93	36·10	5·83	47·10	60	30	4·36	24	1830
7	42·20	36·40	5·80	48·40	61	34	3·64	18	1831
9	37·70	31·16	6·54	44·60	55	28	4·88	26	1832
9	37·36	31·76	5·60	45·40	58	35	1·94	16	1833
8	36·63	31·00	5·63	41·00	61	19	7·04	30	1834
6·3	37·25	33·17	4·08	44·10	59	21	5·13	31	1835
12·1	36·95	30·29	6·66	42·70	54	21	2·97	24	1836
9·0	33·63	28·50	5·13	36·90	55	10·5	5·24	35	1837
8	34·80	31·73	3·07	38·82	58	23	5·88	24	1838
11	36·26	30·80	5·46	39·99	54	28	5·06	22	1839
9	34·86	26·93	7·93	42·57	55	28	8·56	37	1840
6	36·70	32·76	3·94	44·32	69	30	4·58	23	1841
6	34·86	30·46	4·40	40·86	60	26	6·47		1842
	37·75	32·24	5·51	43·40			4·92		Means
12·1	42·20	36·40	7·93	48·40	69		8·56	37	Extremes
	33·63	26·93	3·07	36·90		10·5	1·94		

SATURATION.			WINDS. No. of Days in the Month during which each Wind prevails.								
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Date.
790	377	0·88	3	2	3	1	1	4	7	9	1826
850	428	0·71	1	6	1	6	6	6	2	2	1827
880	525	2·44	6	2	0	2	7	7	3	3	1828
897	556	4·49	2	2	4	0	7	8	3	4	1829
869	457	2·84	0	1	5	3	5	9	5	2	1830
886	555	1·96	2	10	4	3	8	0	2	1	1831
850	408	0·95	6	3	9	3	2	4	2	1	1832
934	589	2·71	4	1	1	2	6	6	5	5	1833
813	347	0·65	5	10	2	8	1	3	0	1	1834
843	356	1·07	8	4	1	0	1	7	6	3	1835
897	437	2·88	5	3	2	2	1	9	5	3	1836
836	289	1·13	5	9	2	0	6	3	4	1	1837
803	438	0·52	10	1	0	1	2	5	4	7	1838
823	478	1·46	2	6	9	1	1	4	4	3	1839
747	365	0·06	6	2	6	2	3	4	4	3	1840
847	432	1·58	1	9	1	0	2	7	5	5	1841
784	441	0·15	3	13	11	2	0	0	0	1	1842
844	439	1·55	4	4·9	3·5	2·1	3·4	5	3·5	3·1	Means
934	289	4·49	10	13	11	8	8	9	7	9	Extremes
747		0·06	0	1	0	0	0	0	0	1	

Date.	TEMPERATURE. Mean Shade.	Max. Shade.	Max. Sun.	Diff.	Mean Max. Shade.	Mean Max. Sun.	Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
1826	53·70	76	102	26	62·40	77·00	14·60	31	22
1827	56·50	81	113	32	66·00	85·00	19·00	32	23
1828	55·88	75	97	22	66·12	86·31	20·19	35	24
1829	55·60	80	101	21	67·41	86·54	18·93	38	29
1830	56·50	81	105	24	66·74	83·70	16·96	35	26
1831	54·50	78	117	39	66·00	88·87	22·87	28	16
1832	52·60	79	105	26	63·32	82·90	19·58	32	24
1833	68·50	86	126	40	74·19	106·00	31·81	39	34
1834	57·30	80	114	34	70·42	94·64	24·22	35	26
1835	54·00	76·5	87·8	10·5	64·76	73·47	8·71	36·5	30·2
1836	52·10	73·7	95	21·3	63·64	82·78	18·14	31·1	21·2
1837	49·62	74·3	88·7	14·4	60·51	73·68	13·17	30·2	23
1838	52·27	78	100	22	64·19	77·86	13·67	26	17
1839	52·45	73	96	23	64·48	82·19	17·71	28	19
1840	56·16	80	95	15	67·00	81·97	14·97	34	27
1841	58·09	82	96	14	69·35	79·13	9·78	36	32
1842	53·73	73	84	11	65·97	72·51	6·54	30	24
Means ..	55·26				66·02	83·20	17·18		
Extremes	68·50 49·62	86	126	40	74·19 60·51	106·00 72·51	31·81 6·54	26	16

Date.	BAROMETER. Mean.	Highest.	Lowest.	Range.	FORCE OF VAPOUR. Mean.	Highest.	Lowest.
1826	30·049	30·419	29·675	0·744	·364	·551	·179
1827	29·813	30·193	29·212	0·981	·428	·611	·233
1828	29·881	30·340	29·440	0·900	·444	·654	·291
1829	30·060	30·441	29·582	0·859	·376	·480	·280
1830	29·879	30·328	29·316	1·012	·425	·632	·270
1831	29·929	30·357	29·452	0·905	·400	·676	·165
1832	29·976	30·437	29·346	1·091	·386	·723	·186
1833	30·119	30·500	29·541	0·959	·484	·611	·260
1834	30·046	30·501	29·435	1·066	·425	·654	·233
1835	29·893	30·196	29·487	0·709	·417	·570	·260
1836	30·181	30·548	29·480	1·068	·345	·463	·147
1837	29·957	30·361	29·636	0·725	·341	·463	·216
1838	29·907	30·416	29·414	1·002	·355	·532	·142
1839	29·974	30·248	29·357	0·891	·352	·699	·172
1840	29·894	30·393	29·425	0·968	·421	·676	·200
1841	29·858	30·364	29·253	1·111	·423	·723	·280
1842	29·903	30·387	29·197	1·190	·407	·514	·200
Means ..	29·959			0·952	·340		
Extremes	30·181 29·813	30·548	29·197	1·190 0·709	·484 ·341	·723	·142

TEMPERATURE.				DEW-POINT.					Date.
Diff.	Mean Min. Shade.	Mean Min Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	
°	°	°	°	°	°	°	°	°	
9	44·00	38·00	6·00	47·00	62	31	6·7	28	1826
9	46·60	40·50	6·10	52·00	65	38	4·7	21	1827
11	45·67	40·22	5·45	53·05	67	44	5·60	22	1828
9	43·87	37·51	6·36	48·90	58	43	7·79	25	1829
9	46·83	34·00	12·83	51·70	66	42	6·01	23	1830
12	43·12	36·67	6·45	50·00	68	29	5·82	24	1831
8	42·00	35·77	6·23	48·80	70	32	5·85	23	1832
5	46·97	41·61	5·36	55·50	65	41	6·16	26	1833
9	44·32	39·61	4·71	51·80	67	38	6·90	26	1834
6·3	43·38	39·77	3·61	51·20	63	41	4·16	20	1835
9·9	40·67	34·89	5·78	45·40	57	26	7·96	35	1836
7·2	38·73	33·20	5·53	45·10	57	36	5·49	26	1837
9	40·35	36·29	4·06	46·32	61	25	8·25	43	1838
9	40·42	35·61	4·81	46·18	69	30	7·79	31	1839
7	45·32	41·35	3·97	51·55	68	34	6·05	27	1840
4	46·83	43·87	2·96	54·59	70	43	5·47	25	1841
6	41·52	36·77	4·75	50·54	60	34	5·61		1842
	43·56	37·97	5·59	50·03			6·25		Means
12	46·97	43·87	12·83	55·50	70		8·25	43·0	Extremes
	40·35	33·20	2·96	45·10		25	4·16		

SATURATION.			WINDS. No. of Days in the Month during which each Wind prevails.								Date.
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	
810	391	2·39	4	14	4	6	0	0	1	2	1826
842	508	2·24	0	1	5	5	6	13	1	0	1827
844	488	1·40	3	4	9	2	6	4	2	1	1828
764	441	0·52	0	11	9	0	1	4	6	0	1829
817	457	2·47	2	1	3	6	2	7	7	3	1830
818	443	2·21	3	5	12	2	6	1	0	2	1831
819	472	2·16	4	6	3	3	8	1	3	3	1832
823	428	0·68	1	5	7	1	8	5	4	0	1833
791	412	1·19	0	5	7	0	11	7	1	0	1834
865	511	3·38	3	1	4	0	4	9	9	1	1835
768	310	1·01	1	13	9	3	1	2	1	1	1836
833	425	1·07	7	6	2	1	5	5	3	2	1837
754	235	0·92	1	15	2	1	6	3	1	2	1838
766	346	0·82	5	10	5	0	4	2	2	3	1839
812	404	2·18	4	1	6	1	6	7	5	1	1840
821	410	2·16	1	7	3	1	5	11	2	1	1841
896	427	1·73	3	5	0	0	7	6	6	4	1842
820	418	1·67	2·4	6·4	5·2	1·2	5·0	5·1	3·1	1·5	Means
896		3·38	7	15	12	6	11	13	7	4	Extremes
754	235	0·52	0	1	0	0	0	0	0	0	

Date.	TEMPERATURE.								
	Mean Shade.	Max. Shade.	Max. Sun.	Diff.	Mean Max. Shade.	Mean Max. Sun.	Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
1826	65·20	93	115	22	74·10	93·40	19·30	44	39
1827	58·50	79	105	26	70·20	92·20	22·00	38	30
1828	62·18	85	105	20	72·00	90·58	18·58	44	40
1829	60·50	84	110	26	72·10	92·03	19·93	37	26
1830	57·50	81	110	29	65·50	85·03	19·53	39	32
1831	61·40	83	110	27	72·06	93·30	21·24	41	32
1832	60·50	81	107	26	70·46	87·40	16·94	41	35
1833	60·60	87	125	38	72·60	100·83	28·23	38	33
1834	62·10	91	121	30	75·00	101·76	26·76	39	33
1835	60·90	86·9	102·2	15·3	73·38	88·86	15·48	37·4	34·7
1836	61·40	86·0	119·3	33·3	71·90	85·93	14·03	43·1	38·6
1837	60·08	80·6	100·4	19·8	72·50	84·20	11·70	35·6	29·3
1838	59·89	83	98	15	70·83	83·26	12·43	35	29
1839	60·16	84	110	26	69·63	89·23	19·60	40	34
1840	60·94	84	100	16	71·96	86·80	14·84	41	34
1841	56·23	80	95	15	67·30	75·43	8·13	36	28
1842	63·56	90	110	20	77·33	94·93	17·60	41	35
Means..	60·68				71·69	89·71	18·60		
Extremes	65·20	93	125	38	77·33	101·76	28·23		
	56·23				65·50	75·43	8·13	35	26

Date.	BAROMETER.				FORCE OF VAPOUR.		
	Mean.	Highest.	Lowest.	Range.	Mean.	Highest.	Lowest.
1826	30·280	30·489	29·905	·584	·492	·654	·302
1827	29·963	30·354	29·617	·737	·460	·590	·291
1828	30·009	30·337	29·323	1·014	·457	·676	·324
1829	30·049	30·418	29·420	·998	·460	·699	·224
1830	29·832	30·150	29·415	·735	·473	·699	·270
1831	29·962	30·211	29·646	·665	·501	·773	·260
1832	29·883	30·416	29·463	·953	·542	·773	·336
1833	29·846	30·403	29·414	1·089	·501	·676	·324
1834	29·991	30·399	29·654	·745	·457	·676	·270
1835	30·048	30·375	29·253	1·122	·510	·748	·280
1836	29·941	30·325	29·571	·854	·522	·799	·302
1837	30·009	30·361	29·564	·797	·502	·773	·242
1838	29·891	30·322	29·493	·829	·501	·773	·260
1839	29·905	30·291	29·409	·882	·531	·826	·302
1840	29·966	30·195	29·659	·536	·491	·654	·260
1841	29·92[illegible]	30·357	29·494	·863	·413	·676	·270
1842	29·992	30·296	29·420	·876	·526	·799	·324
Means ..	29·970			·840	·490		
Extremes	30·280	30·489		1·122	·542	·826	
	29·832		29·253	0·536	·413		·224

TEMPERATURE.				DEW-POINT.					Date.
Diff.	Mean Min. Shade.	Mean Min. Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	
°	°	°	°	°	°	°	°	°	
5	57·10	47·30	10·80	56·70	67	45	8·50	28	1826
8	49·00	44·00	5·00	54·90	64	44	6·80	27	1827
4	52·36	46·55	5·81	57·80	68	47	6·56	24	1828
11	48·90	42·07	5·83	54·40	69	37	6·84	25	1829
7	49·50	44·73	4·77	54·80	69	42	4·85	22	1830
9	50·93	45·30	5·63	56·50	72	41	5·81	28	1831
6	50·70	45·56	5·14	58·90	72	48	4·09	19	1832
5	48·73	44·23	4·50	56·50	68	47	5·75	30	1833
6	49·23	44·36	4·87	54·60	68	42	9·26	35	1834
2·7	48·59	45·48	3·11	57·10	71·5	43	6·04	28	1835
4·5	50·95	48·05	2·90	57·80	73·5	45	5·49	33	1836
6·3	47·67	44·04	3·63	56·60	72	39	6·03	36	1837
6	48·96	45·73	3·23	56·61	72	41	4·24	24	1838
6	50·70	46 93	3·77	58·34	74	45	4·29	20	1839
7	49·93	45·70	4·23	55·95	67	41	6·61	25	1840
8	45·16	42·37	2·79	53·79	68	42	4·85	28	1841
6	49·80	41·50	8·30	58·08	73	47	8·94		1842
	49·89	44·92	4·95	56·43			6·17		Means
11	57·10	48·05	10·80	58·90	74		9·26	36	Extremes
	45·16	41·50	2·79	53·79		37	4·09		

SATURATION.			WINDS. No. of Days in the Month during which each Wind prevails.								Date.
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	
·748	400	0·38	1	11	5	2	0	2	1	8	1826
·797	414	0·82	0	5	3	1	5	8	4	3	1827
798	457	1·94	0	3	5	2	0	8	9	3	1828
797	441	2·37	1	6	2	1	5	7	3	4	1829
853	488	2·62	1	2	4	1	0	10	8	4	1830
833	391	1·37	4	1	0	0	0	14	9	2	1831
881	523	2·89	2	3	1	2	5	10	5	2	1832
835	377	2·63	0	0	0	2	4	6	17	1	1833
740	320	1·63	2	1	2	2	9	5	8	1	1834
822	411	1·99	7	4	0	3	5	4	5	2	1835
842	357	1·66	0	1	1	1	12	10	4	1	1836
827	300	1·31	0	5	5	2	6	2	2	8	1837
873	457	3·65	2	2	4	0	12	7	3	0	1838
874	519	3·00	1	3	4	3	8	8	2	1	1839
811	450	1·48	0	0	1	1	2	9	13	4	1840
842	373	2·45	4	4	0	0	5	5	[illegible]	5	1841
752	435	1·58	0	8	3	1	2	7	6	3	1842
819	418	1·98	1·4	3·4	2·3	1·4	4·7	7·1	6·2	3·0	Means
881		3·65	7	11	5	3	12	14	17	8	Extremes
740	300	0·38	0	0	0	0	0	2	1	0	

Date.	TEMPERATURE. Mean Shade.	Max. Shade.	Max. Sun.	Diff.	Mean Max. Shade.	Mean Max. Sun.	Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
1826	67·80	89	116	27	78·20	98·60	20·40	46	37
1827	66·50	89	118	29	77·50	100·00	22·50	44	34
1828	63·55	84	98	14	72·50	85·10	12·60	43	35
1829	61·30	78	104	26	70·50	86·12	15·62	42	34
1830	64·20	88	117	29	74·25	96·51	22·26	45	39
1831	64·80	86	117	31	77·00	100·00	23·00	47	40
1832	61·80	84	109	25	73·25	93·58	20·33	41	35
1833	62·20	86	126	40	74·48	104·93	30·45	40	32
1834	66·00	94	130	36	76·87	100·51	23·64	46	42
1835	64·40	90·9	116·6	25·7	78·06	100·13	32·07	42·8	41·1
1836	63·60	94·4	128·3	33·9	75·94	101·01	25·07	42·8	39·2
1837	63·16	85·1	104	18·9	75·74	87·62	17·88	37·4	31·1
1838	62·78	84	107	23	74·48	87·51	13·03	40	33
1839	61·74	81	101	21	70·58	85·61	15·03	45	40
1840	60·06	80	105	25	69·35	87·09	17·74	41	34
1841	59·30	79	84	5	68·61	74·06	5·45	42	36
1842	60·80	84	107	23	72·29	91·29	19·00	40	33
Means ..	63·17				74·09	93·51	19·42		
Extremes	67·80	94·4	130	40	78·20	104·93	32·07		
	59·30				68·61	74·06	5·45	37·4	31·1

Date.	BAROMETER. Mean.	Highest.	Lowest.	Range.	FORCE OF VAPOUR. Mean.	Highest.	Lowest.
1826	30·008	30·381	29·644	·737	·560	·723	·324
1827	30·115	30·475	29·755	·720	·526	·748	·349
1828	29·722	30·017	29·298	·719	·577	·799	·361
1829	29·818	30·224	29·281	·943	·543	·723	·361
1830	29·944	30·407	29·724	·783	·579	·973	·302
1831	29·976	30·364	29·584	·780	·568	·799	·361
1832	30·109	30·407	29·724	·683	·528	·773	·260
1833	30·031	30·458	29·612	·846	·545	·699	·324
1834	29·958	30·295	29·461	·834	·580	·799	·375
1835	30·061	30·275	29·744	·531	·493	·826	·336
1836	30·002	30·418	29·441	·979	·514	·676	·291
1837	29·969	30·332	29·293	1·039	·551	·773	·224
1838	29·992	30·283	29·620	·663	·523	·773	·260
1839	29·911	30·304	29·298	1·006	·553	·723	·313
1840	29·844	30·269	29·434	·835	·469	·611	·260
1841	29·819	30·133	29·266	·867	·463	·676	·313
1842	29·919	30·388	29·611	·777	·518	·748	·313
Means ..	29·952			·808	·534		
Extremes	30·115	30·475		1·039	·580	·973	
	29·818		29·266	0·663	·463		·224

TEMPERATURE.				DEW-POINT.					
Diff.	Mean Min. Shade.	Mean Min. Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	Date.
°	°	°	°	°	°	°	°	°	
9	55·00	47·30	7·70	60·10	70	47	7·70	28	1826
10	53·00	47·00	6·00	58·60	71	49	9·10	27	1827
8	54·60	49·90	4·70	61·50	73	50	3·18	21	1828
8	52·19	46·29	5·90	59·00	70	50	2·88	20	1829
6	54·22	49·64	4·58	61·10	79	45	4·96	24	1830
7	52·71	47·96	4·75	60·50	73	50	5·84	26	1831
6	50·38	45·19	5·19	58·10	72	41	6·13	24	1832
8	49·93	45·10	4·83	59·10	69	47	4·25	25	1833
4	55·16	52·67	2·49	61·10	73	51	5·71	25	1834
1·7	50·06	47·62	2·44	58·30	74	48	8·70	32	1835
3·6	51·33	47·53	3·80	57·30	68	44	7·29	33	1836
6·3	50·57	48·12	2·45	59·50	72	37·5	6·23	38	1837
7	51·09	48·35	2·74	57·84	72	41	5·11	20	1838
5	52·90	49·16	3·74	59·61	70	46	4·67	28	1839
7	50·77	46·44	4·33	54·58	65	41	7·07	27	1840
6	50·00	47·58	2·42	57·01	68	46	3·97	19	1841
7	49·32	46·67	2·65	56·38	71	46	5·36		1842
	51·95	47·79	4·18	58·80			5·77		Means
10	55·16 49·32	52·67 45·10	7·70 2·42	61·50 54·58	79	37·5	9·10 2·88	38	Extremes

SATURATION.			WINDS. No. of Days in the Month during which each Wind prevails.								
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Date.
815	413	2·07	0	4	2	2	3	8	9	3	1826
752	420	1·31	0	1	3	2	3	9	8	5	1827
907	515	4·38	1	0	1	1	6	12	6	4	1828
941	520	5·23	3	4	1	2	6	9	5	1	1829
875	457	1·46	0	1	5	0	8	5	12	0	1830
[illegible]	436	2·52	1	1	8	0	0	10	9	2	1831
824	446	0·89	1	7	4	0	2	3	9	5	1832
876	442	1·56	3	4	3	1	2	7	9	2	1833
834	452	6·34	1	1	6	1	8	8	4	2	1834
706	360	0·41	1	1	6	1	6	11	5	0	1835
790	348	1·78	1	0	0	1	6	9	10	4	1836
849	273	1·78	1	1	5	2	2	8	7	5	1837
865	506	2·19	2	1	0	1	4	11	9	3	1838
862	401	2·92	0	4	1	0	8	15	2	1	1839
797	404	1·68	0	2	0	0	2	12	10	5	1840
872	512	3·56	1	3	0	0	2	10	[illegible]	5	1841
843	443	1·52	6	2	4	2	2	7	7	1	1842
837·4	432	2·44	1·2	2·1	2·8	0·9	4·1	9	7·1	2·8	Means
941 706	273	6·34 0·41	6 0	7 0	8 0	2 0	8 0	15 3	12 2	5 0	Extremes

Date.	TEMPERATURE.								
	Mean Shade.	Max. Shade.	Max. Sun.	Diff.	Mean Max. Shade.	Mean Max. Sun.	Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
1826	67·00	88	112	24	77·00	93·00	16·00	42	32
1827	64·00	86	112	26	71·00	93·00	22·00	42	32
1828	61·00	78	96	18	70·00	84·00	14·00	44	37
1829	60·10	81	103	22	68·61	82·93	14·32	40	33
1830	60·10	80	112	22	70·70	95·48	24·78	38	30
1831	65·40	84	109	25	76·61	98·74	22·13	45	39
1832	62·70	85	110	25	73·58	91·22	17·64	42	35
1833	59·40	80	117	37	72·35	96·74	24·39	36	29
1834	62·90	85	120	35	73·71	98·00	24·29	40	34
1835	65·50	92·3	120	27·7	80·32	107·00	26·68	41	35·1
1836	60·60	84·2	95	10·8	72·03	87·56	15·53	40·1	36·1
1837	62·53	86·9	113·9	27·0	74·02	86·55	12·53	39·2	34·7
1838	61·58	82	97	15	72·42	85·00	12·58	38	32
1839	61·41	85	104	19	72·25	88·06	15·81	37	29
1840	64·34	87	108	21	76·00	92·71	16·71	41	36
1841	62·48	81	102	21	72·03	79·61	7·58	41	36
1842	66·27	93	120	27	78·29	97.41	19·12	43	38
Means..	62·78				73·58	91·58	18·00		
Extremes	67·00	93	120	37	80·32	107·00	26·68		
	59·40				68·61	79·61	7·58	36	29

Date.	BAROMETER.				FORCE OF VAPOUR.		
	Mean.	Highest.	Lowest.	Range.	Mean.	Highest.	Lowest.
1826	30·381	30·444	29·677	0·767	·577	·723	·375
1827	30·034	30·452	29·363	1·089	·492	·611	·324
1828	29·882	30·340	29·406	0·934	·543	·723	·389
1829	29·892	30·250	29·254	0·996	·508	·723	·324
1830	29·889	30·303	29·291	1·012	·498	·699	·336
1831	29·956	30·258	29·642	0·616	·589	·773	·280
1832	29·889	30·313	29·156	1·157	·556	·773	·361
1833	29·979	30·394	28·985	1·409	·436	·632	·251
1834	29·900	30·187	29·624	0·563	·577	·882	·324
1835	29·996	30·355	29·522	0·833	·535	·676	·336
1836	30·042	30·340	29·602	0·738	·506	·632	·313
1837	30·002	30·460	29·388	1·072	·578	·854	·302
1838	29·932	30·249	29·249	1·000	·514	·676	·302
1839	30·003	30·325	29·172	1·153	·522	·723	·280
1840	29·883	30·223	29·169	1·054	·490	·699	·291
1841	29·860	30·244	29·385	0·859	·507	·773	·302
1842	29·993	30·399	29·621	0·778	·592	·854	·302
Means..	29·971			0·943	·530		
Extremes	30·381	30·460		1·409	·589	·882	
	29·860		28·985	0·563	·439		·251

TEMPERATURE.				DEW-POINT.					Date.
Diff.	Mean Min. Shade.	Mean Min. Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	
o	o	o	o	o	o	o	o	o	
10	53·00	45·00	8·00	61·00	70	51	6·	24	1826
10	50·07	44·00	6·07	56·60	65	47	6·7	26	1827
7	52·00	47·00	5·00	59·40	70	52	2·98	17	1828
7	51·64	46·80	4·84	57·80	70	47	2·95	16	1829
8	49·67	44·93	4·74	56·40	69	48	4·79	20	1830
6	54·19	49·67	4·52	61·70	72	43	4·58	25	1831
7	51·93	47·28	4·65	59·80	72	50	3·72	27	1832
7	46·45	40·48	5·97	52·50	66	40	8·08	26	1833
6	52·16	48·54	3·62	59·90	76	47	5·06	20	1834
5.9	50·77	47·06	3·71	58·50	68	48	7·48	20	1835
4·0	49·20	45·62	3·58	56·80	66·5	46	5·04	28	1836
4·5	51·04	48·27	2·77	61·10	75·0	45	3·15	27	1837
6	56·74	48·06	8·68	57·35	68	45	4·94	23	1838
8	50·58	45·96	4·62	57·82	70	43	4.61	24	1839
5	52·68	48·22	4·46	58·06	69	44	6·02	24	1840
5	52·93	49·84	3·09	59·60	72	45	2·73	19	1841
5	54·25	50·32	3·93	61·93	75	45	5·34		1842
	51·72	46·88	4·84	58·60			4·95		Means
10	56·74 46·45	50·32 40·48	8·68 2·77	61·93 52·50	76	40	8·08 2·73	28	Extremes

SATURATION.			WINDS. No. of Days in the Month during which each Wind prevails.								Date.
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	
825	553	2·00	0	2	0	5	5	13	5	1	1826
800	440	1·66	1	3	1	3	8	3	6	6	1827
914	579	4·35	0	3	4	1	5	9	6	3	1828
907	592	4·07	1	3	0	0	8	4	8	7	1829
858	524	3·05	0	1	2	1	3	8	14	2	1830
861	441	1·59	4	2	4	0	6	3	10	2	1831
888	415	3·62	0	0	4	2	5	8	12	0	1832
766	415	1·93	4	7	0	0	1	4	12	3	1833
840	522	2·73	1	5	1	1	7	10	5	1	1834
789	402	0·18	1	4	11	1	5	4	2	3	1835
853	452	1·97	1	6	4	1	6	6	6	1	1836
901	488	3·04	1	7	3	2	7	7	2	2	1837
856	486	1·23	2	0	0	1	6	14	4	4	1838
864	457	1·85	2	2	1	0	3	8	8	7	1839
822	324	1·62	0	3	6	0	4	7	10	1	1840
910	520	2·69	2	0	0	0	7	12	8	2	1841
839	453	2·81	1	7	7	1	3	6	5	1	1842
852	474	2·37	1·2	3·2	2·8	1·1	5·2	7·4	7·2	2·7	Means
914 766	324	4·35 0·18	4 0	7 0	11 0	5 0	8 1	14 3	14 2	7 0	Extremes

Date.	TEMPERATURE.								
	Mean Shade.	Max Shade.	Max. Sun.	Diff.	Mean Max. Shade.	Mean Max. Sun.	Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
1826	59·40	76·0	101	25·0	67·80	81·20	13·40	34·0	28·0
1827	56·50	72·0	100	28·0	67·70	84·80	17·10	41·0	32
1828	59·55	79	107	28	69·40	87·10	17·70	37	30
1829	55·20	70	94	24	64·90	81·00	16·10	34	25
1830	55·10	75	103	28	65·06	82·80	17·74	32	28
1831	58·60	76	99	23	68·43	86·96	18·53	37	31
1832	57·40	82	106	24	69·46	90·36	20·90	34	27
1833	54·50	72	98	26	65·16	82·36	17·20	34	29
1834	59·20	78	106	28	70·10	92·30	22·20	37	32
1835	58·30	83·3	113·9	30·6	69·80	85·49	15·69	38·3	34·7
1836	54·80	73·4	94·1	20·7	63·32	74·12	10·80	32·0	25·3
1837	55·68	72·5	91·4	18·9	65·15	80·16	15·01	35	29·3
1838	56·16	76	98	22	67·06	78·93	11·87	34	26
1839	57·71	78	93	15	67·36	77·73	10·37	36	33
1840	53·98	80	100	20	63·93	80·26	16.33	29	23
1841	59·44	84	104	20	68·83	83·56	14·73	36	31
1842	57·56	81	108	27	66·40	84·63	18·23	38	34
Means ..	57·00				67·05	83·16	16·11		
Extremes	59·55 53·98	84	113·9	30·6	70·10 63·32	92·30 74·12	22·20 10·37	29	23

Date.	BAROMETER.				FORCE OF VAPOUR.		
	Mean.	Highest.	Lowest.	Range.	Mean.	Highest.	Lowest.
1826	29·903	30·326	29·113	1·213	·492	·723	·270
1827	30·011	30·394	29·513	0·881	·492	·676	·270
1828	29·969	30·594	29·418	1·176	·508	·723	·270
1829	29·770	30·257	29·151	1·106	·428	·611	·233
1830	29·793	30·411	29·211	1·200	·452	·611	·260
1831	29·931	30·270	29·582	0·688	·505	·773	·324
1832	30·149	30·557	29·638	0·919	·471	·699	·216
1833	29·914	30·377	29·409	0·968	·428	·611	·260
1834	30·084	30·527	29·387	1·140	·459	·699	·313
1835	29·729	30·226	29·132	1·094	·485	·676	·260
1836	29·875	30·288	29·270	1·018	·439	·676	·242
1837	29·894	30·313	29·071	1·242	·476	·676	·280
1838	30·000	30·549	29·272	1·277	·453	·699	·260
1839	29·679	30·131	29·061	1·070	·494	·699	·270
1840	29·764	30·196	28·744	1·452	·407	·611	·242
1841	29·725	30·109	29·167	0·842	·468	·799	·260
1842	29·811	30·200	29·341	0·859	·504	·854	·251
Means ..	29·882			1·067	·468		
Extremes	30·149 29·679	30·594	28·744	1·452 0·688	·508 ·407	·854	·216

TEMPERATURE.				DEW-POINT.					Date.
Diff.	Mean Min. Shade.	Mean Min. Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	
°	°	°	°	°	°	°	°	°	
6	49·00	46·00	3·00	56·70	70	42	2·70	14	1826
9	50·60	45·00	5·60	56·30	68	42	3·60	18	1827
7	49·70	44·30	5·40	57·30	70	42	3·10	24	1828
9	45·60	39·70	5·90	52·80	65	38	2·54	14	1829
4	45·23	40·40	4·80	53·50	65	41	2·65	17	1830
6	48·93	44·16	4·77	56·80	72	47	2·04	12	1831
7	45·43	40·30	5·13	54·70	69	36	2·88	19	1832
5	44·00	39·56	4·44	52·00	65	41	3·38	17	1833
5	48·33	44·90	3·43	56·80	69	46	3·10	14	1834
3·6	46·94	43·61	3·33	55·60	68	41	3·87	29	1835
6·7	46·31	42·28	4·03	52·80	68	39	2·09	15	1836
5·7	46·22	43·12	3·10	55·00	68	43	2·68	17	1837
8	45·26	41·43	3·83	53·62	69	41	2·70	17·2	1838
3	48·06	44·40	3·66	56·13	69	42	1·75	15	1839
6	44·03	38·83	5·20	50·54	65	39	3·83	23	1840
5	49·66	46·46	3·20	57·53	73	41	1·73	16	1841
4	48·73	45·63	3·10	56·81	75	40	1·77		1842
	47·17	42·94	4·23	53·81			2·73		Means
9	44·00	46·46	5·90	57·53	75		3·87	29	Extremes
	50·60	38·83	3·00	52·00		36	1·73		

SATURATION.			WINDS No. of Days in the Month during which each Wind prevails.								Date.
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	
906	622	3·71	0	7	1	5	4	7	4	2	1826
906	439	3·37	3	6	0	4	3	4	4	6	1827
935	464	4·03	0	5	8	3	1	8	4	1	1828
899	628	3·71	3	5	1	1	6	5	4	5	1829
910	574	3·21	0	0	0	0	6	12	10	2	1830
935	673	4·19	4	1	3	0	10	6	2	4	1831
909	541	1·12	2	1	3	0	4	2	15	3	1832
836	555	1·55	2	5	3	0	10	2	7	1	1833
825	616	0·83	0	1	6	3	8	6	6	0	1834
880	390	4·60	0	0	0	3	14	7	5	1	1835
926	616	3·81	4	4	0	0	5	9	8	0	1836
915	576	0.91	3	4	6	3	6	5	2	1	1837
879	506	2·08	2	4	3	0	2	4	8	7	1838
941	610	3·92	1	0	1	1	11	13	3	0	1839
875	457	2·45	2	1	2	0	4	7	14	0	1840
934	571	3·71	0	1	4	3	13	6	3	0	1841
942	665	3·39	1	8	5	1	2	5	6	2	1842
906	559	2·97	1·5	3·1	2·7	1·5	6·4	6·3	6·1	2·1	Means.
942		4·60	4	8	8	5	14	13	15	7	Extremes
825	390	0·83	0	0	0	0	1	2	2	0	

Date.	TEMPERATURE.								
	Mean Shade.	Max. Shade.	Max. Sun.	Diff.	Mean Max Shade.	Mean Max. Sun.	Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
1826	53·80	72	85	13	61·20	70·60	9·40	29	22
1827	49·00	67	93	26	60·70	75·40	14·70	31	24
1828	51·00	70	87	17	60·00	73·00	13·00	28	20
1829	48·70	65	82	17	56·87	68·19	11·32	29	20
1830	51·70	73	90	17	61·32	74·73	13·41	29	21
1831	56·50	73	86	13	64·20	72·41	8·21	31	26
1832	51·50	72	96	24	60·00	81·22	21·22	31	26
1833	51·10	68	97	29	61·25	81·42	20·17	29	23
1834	52·50	80	107	27	61·51	72·25	10·74	32	25
1835	48·70	63·9	77	13·1	57·38	64·95	7·57	27·8	23·5
1836	48·40	65·3	76·1	10·8	56·03	63·50	7·47	23	14
1837	50·00	73·4	89·6	16·2	60·63	73·40	12·77	27·1	22·1
1838	50·48	66	76	10	57·58	64·61	7·03	26	18
1839	51·40	71	83	12	58·58	66·90	8·32	35	28
1840	46·54	66	89	23	56·32	74·39	18·07	28	21
1841	49·86	64	79	15	57·09	62·35	5·26	26	22
1842	45·02	64	100	36	55·19	72·19	17·00	20	12
Means ..	50·37				59·16	71·26	12·10		
Extremes	56·50 45·02	80	107	36	64·20 55·19	81·42 62·35		20	12

Date.	BAROMETER.				FORCE OF VAPOUR.		
	Mean.	Highest.	Lowest.	Range.	Mean.	Highest.	Lowest.
1826	29·949	30·279	29·409	0·870	·428	·632	·193
1827	29·772	30·549	29·022	1·527	·414	·532	·208
1828	30·096	30·503	29·348	1·155	·388	·611	·208
1829	30·030	30·458	29·413	1·045	·352	·570	·172
1830	30·239	30·550	29·685	0·865	·406	·590	·200
1831	29·887	30·423	29·246	1·177	·498	·632	·313
1832	30·090	30·471	29·166	1·305	·420	·590	·233
1833	29·820	30·303	29·188	1·115	·400	·590	·242
1834	30·055	30·674	29·313	1·361	·364	·632	·142
1835	29·806	30·431	28·871	1·560	·374	·532	·193
1836	29·838	30·495	28·940	1·555	·370	·570	·147
1837	30·119	30·713	29·287	1·426	·401	·570	·208
1838	29·987	30·457	29.280	1·177	·396	·551	·179
1839	30·017	30·480	29·447	1·033	·392	·632	·208
1840	29·938	30·549	29·126	1·423	·326	·417	·193
1841	29·538	30·162	28·808	1·354	·355	·532	·186
1842	29·954	30·490	28·802	1·688	·333	·432	·159
Means ..	29·949			1·273	·389		
Extremes	30·239 29·538	30·713	28·802	1·688 0·865	·498 ·326	·632	·142

TEMPERATURE.				DEW-POINT.					Date.
Diff.	Mean Min. Shade.	Mean Min. Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	
°	°	°	°	°	°	°	°	°	
7	45·10	39·20	5·90	52·12	66	33	1·68	11	1826
7	45·00	39·30	5·70	51·60	61	35	1·90	9	1827
8	42·00	36·00	6·00	49·10	65	35	2·13	11	1828
9	40·54	34·09	6·45	46·50	63	30	2·41	15	1829
8	42·22	36·96	5·26	50·40	64	34	2·08	13	1830
5	48·83	44·35	4·48	56·40	66	46	1·06	9	1831
5	43·12	38·51	4·61	51·40	64	38	0·54	6	1832
6	41·09	37·25	3·84	51·10	64	39	1·52	12	1833
7	43·61	39·77	3·84	47·10	66	25	3·21	16	1834
4·3	40·14	36·49	3·65	47·80	61	33	1·51	10	1835
9·0	40·94	37·00	3·94	47·50	63·5	26	0·88	13	1836
5·0	39·36	35·60	3·76	50·00	63·5	35	1·67	13	1837
8	43·38	39·12	4·26	49·73	62	31	2·19	15	1838
7	44·23	39·71	4·52	49·39	66	35	1·64	10	1839
7	36·96	31·61	5·35	43·86	54	33	2·32	15	1840
4	42·64	39·96	2·68	49·55	61	32	1·43	15	1841
8	34·80	30·19	4·61	44·41	55	28	2·44		1842
	41·99	37·36	4·63	49·29			1·80		Means
9	48·83	44·35	6·45	56·40	66		3·21	16	Extremes
	34·80	30·19	2·68	43·86		25	0·54		

SATURATION.			WINDS. No. of Days in the Month during which each Wind prevails.								Date.
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	
964	696	2·14	0	1	2	2	5	9	5	7	1826
932	774	4·06	2	1	2	4	6	5	5	5	1827
937	703	1·18	1	4	5	1	3	8	6	3	1828
936	660	1·60	4	6	3	0	2	5	5	6	1829
931	634	0·98	3	3	5	1	7	2	8	2	1830
965	741	3·81	0	0	1	1	19	8	2	0	1831
981	788	3·09	0	4	3	0	8	10	6	0	1832
941	657	2·35	1	5	5	1	7	6	3	3	1833
903	612	0·43	2	2	3	0	11	5	5	3	1834
954	708	4·05	0	2	2	4	6	5	9	3	1835*
973	654	3·62	1	0	3	2	7	11	3	4	1836
945	655	2·39	2	2	1	0	6	12	8	0	1837
929	506	2·36	2	7	1	1	2	9	5	4	1838
946	714	2·23	2	6	2	4	12	2	2	1	1839
923	593	1·35	6	2	4	2	1	1	7	8	1840
970	581	4·61	1	6	0	2	3	6	9	4	1841
919	608	1·71	1	13	1	1	0	9	4	2	1842
944	616	2·46	1·6	3·7	2·5	1·5	6·1	6·6	5·4	3·2	Means
981		4·61	6	13	5	4	19	12	9	7	Extremes
903	506	0·43	0	0	0	0	0	1	2	0	

Date.	TEMPERATURE.								
	Mean Shade.	Max. Shade.	Max. Sun.	Diff.	Mean Max. Shade.	Mean Max. Sun.	Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
1826	41·90	55	72	17	47·90	55·70	8·80	21	20
1827	40·00	60	73	13	49·30	57·40	8·10	20	10
1828	45·50	60	79	19	52·30	61·70	9·40	21	19
1829	40·40	59	72	13	46·83	54·43	7·60	21	15
1830	44·60	63	77	14	52·50	60·03	7·53	25	18
1831	43·00	58	67	9	49·90	55·76	5·86	25	15
1832	43·70	61	67	6	49·56	57·36	7·80	31	24
1833	43·60	62	77	15	50·76	59·86	9·10	24	17
1834	45·10	63	80	17	51·63	59·63	8·00	25	20
1835	44·90	58·1	63·5	5·4	50·09	53·04	2·95	28·4	22·5
1836	43·40	58·1	63·5	5·4	50·01	53·63	3·62	23·0	17·6
1837	40·22	55·4	61·7	6·3	47·89	53·97	6·08	22·1	14·9
1838	42·49	61	70	9	48·90	53·13	4·23	23	15
1839	45·56	56	61	5	51·06	52·76	1·70	21	15
1840	43·16	58	73	15	49·96	54·66	4·70	22	14
1841	42·60	63	73	10	49·90	56·90	7·00	15	10
1842	42·91	55	65	10	49·03	52·60	3·57	26	20
Means ..	43·12				50·44	56·03	6·23		
Extremes	45·56	63	80	19	52·50	61·70	9·40		
	40·00				46·83	52·60	1·70	15	10

Date.	BAROMETER.				FORCE OF VAPOUR.		
	Mean.	Highest.	Lowest.	Range.	Mean.	Highest.	Lowest.
1826	29·858	30·529	28·752	1·777	·280	·389	·136
1827	30·029	30·485	29·401	1·084	·316	·480	·112
1828	29·913	30·374	29·241	1·133	·328	·447	·142
1829	30·053	30·471	29·551	0·920	·272	·480	·142
1830	29·854	30·459	29·131	1·328	·338	·497	·172
1831	29·931	30·578	29·287	1·291	·319	·463	·165
1832	29·875	30·482	29·490	0·992	·334	·497	·216
1833	29·953	30·309	29·175	1·134	·308	·463	·142
1834	29·957	30·452	29·102	1·350	·317	·532	·159
1835	29·961	30·471	29·152	1·319	·318	·532	·186
1836	29·653	30·165	29·016	1·149	·302	·447	·153
1837	29·861	30·477	28·801	1·676	·281	·463	·131
1838	29·560	30·462	28·673	1·789	·296	·463	·142
1839	29·695	30·272	28·978	1·294	·356	·432	·147
1840	29·601	30·433	28·669	1·764	·318	·532	·136
1841	29·746	30·391	28·845	1·546	·280	·432	·126
1842	29·680	30·582	28·703	1·879	·317	·432	·186
Means ..	29·834			1·377	·310		
Extremes	30·053	30·578		1·879	·356	·532	
	29·560		28·669	0·920	·272		·112

TEMPERATURE.				DEW-POINT.					Date.
Diff.	Mean Min. Shade.	Mean Min. Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	
°	°	°	°	°	°	°	°	°	
1	35·20	30·80	4·40	40·30	52	24	1·6	16	1826
10	38·00	33·40	4·60	43·30	58	19	1·5	11	1827
2	38·70	33·80	4·90	44·70	56	25	1·3	9	1828
6	33·96	29·23	4·73	39·60	58	25	1·45	13	1829
7	36·86	32·43	4·43	44·90	59	30	1·0	11	1830
10	37·93	31·56	6·37	43·29	57	29	0·74	9	1831
7	37·96	33·23	4·73	44·50	59	36	0·38	9	1832
7	36·46	33·06	3·40	42·30	57	25	1·50	12	1833
5	38·70	34·60	4·10	43·10	61	28	1·95	10	1834
5·9	39·92	35·13	4·79	43·20	61	32	1·15	10	1835
5·4	36·89	31·70	5·19	41·80	56	27	0·72	10	1836
7·2	32·55	28·04	4·51	40·10	57	23	0·83	8	1837
8	36·09	32·46	3·63	41·36	57	25	0·58	6	1838
6	40·06	36·16	3·90	46·35	55	26	0·47	9	1839
8	36·46	31·87	4·59	43·20	61	24	0·48	8	1840
5	35·30	32·43	2·87	43·02	55	22	0·91	14	1841
6	36·80	33·03	3·77	43·12	55	32	0·82		1842
	36·93	32·48	4·14	42·82			1·02		Means
10	32·55	36·16	6·37	46·35	61		1·95	16	Extremes
	40·06	28·04	2·87	39·60		19	0·38		

SATURATION.			WINDS. No. of Days in the Month during which each Wind prevails.								Date.
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	
959	822	2·89	2	6	0	1	6	2	3	10	1826
963	680	1·06	2	1	2	4	6	5	5	5	1827
931	738	1·12	0	3	3	5	4	3	6	6	1828
931	632	1·86	4	7	2	3	4	4	3	3	1829
965	680	3·05	0	0	6	0	13	6	5	0	1830
972	734	1·70	0	1	2	1	3	12	8	3	1831
985	738	1·94	1	5	4	5	3	6	5	1	1832
944	660	2·38	0	0	1	1	8	13	6	1	1833
932	714	1·75	1	9	6	0	2	9	2	1	1834
957	705	1·94	4	2	1	4	12	5	2	0	1835
974	705	3·60	0	1	0	2	2	17	5	3	1836
965	766	1·32	4	4	0	0	2	6	9	5	1837
976	812	3·55	2	7	9	5	2	4	1	0	1838
987	734	4·37	0	4	7	4	6	5	2	2	1839
981	741	3·59	1	6	3	1	5	10	3	1	1840
966	594	3·41	0	2	3	3	5	7	7	3	1841
938	681	4·47	0	7	6	0	6	7	3	1	1842
960	·713	2·58	1·2	3·8	3·2	2·2	5·2	7·1	4·4	2·6	Means
987		4·47	4	9	7	5	13	17	9	10	Extremes
931	594	1·06	0	0	0	0	2	2	1	0	

Date.	TEMPERATURE.								
	Mean Shade.	Max. Shade.	Max. Sun.	Diff.	Mean Max. Shade.	Mean Max Sun.	Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
1826	44·10	56·0	67·0	9·0	48·00	54·00	6·00	27·0	21
1827	42·50	58·0	65·0	7·0	49·60	54·40	4·80	27·0	19
1828	44·70	56·0	65	9	50·10	55·30	5·20	26	15
1829	33·30	51	60	9	37·38	39·67	1·29	15	12
1830	35·50	53	61	8	40·41	45·48	5·07	10	6
1831	42·50	57	61	4	48·09	51·74	3·65	24	16
1832	41·90	57	59	2	47·58	50·51	2·93	27	20
1833	45·60	56	69	13	51·54	57·12	5·48	28	22
1834	40·70	56	63	7	46·38	51·93	5·55	25	16
1835	34·20	54·9	63·5	8·6	38·85	42·96	4·11	16·2	8·6
1836	40·60	56·3	63·0	6·7	45·34	46·11	0·67	26·0	18·5
1837	41·38	54·5	59·9	5·4	46·61	49·64	3·03	23·9	15·8
1838	38·67	56	60	4	44·64	47·67	3·03	21	14
1839	40·30	57	57	0	45·35	46·70	1·35	21	15
1840	32·00	56	57	1	37·55	38·03	0·48	15	10
1841	39·59	55	61	6	45·80	48·87	3·07	16	9
1842	44·07	61	65	4	49·80	52·16	2·36	25	21
Means ..	40·09				45·47	48·95	3·48		
Extremes	32·00 45·60	61	69	13	51·54 37·38	57·12 38·03	6·00 0·67	10	8·60

Date.	BAROMETER.				FORCE OF VAPOUR.		
	Mean.	Highest.	Lowest.	Range.	Mean.	Highest.	Lowest.
1826	29·996	30·626	29·217	1·389	·304	·417	·153
1827	29·875	30·729	29·042	1·687	·328	·417	·153
1828	30·010	30·475	29·248	1·227	·328	·417	·159
1829	30·168	30·656	29·683	0·973	·216	·336	·103
1830	29·646	30·446	28·910	1·536	·239	·349	·084
1831	29·824	30·494	28·943	1·551	·309	·447	·159
1832	30·004	30·526	29·527	0·999	·302	·447	·165
1833	29·741	30·191	29·241	0·950	·338	·447	·186
1834	30·331	30·667	20·268	1·399	·289	·417	·153
1835	30·203	30·624	29.336	1·288	·238	·389	·107
1836	29·830	30·474	28·963	1·511	·279	·447	·136
1837	29·964	30·534	29·273	1·261	·287	.432	·153
1838	30·102	30·601	29·312	1·389	·269	·417	·172
1839	29·735	30·508	29·190	1·318	·278	·447	·153
1840	30·092	30·644	29·229	1·415	·212	·447	·099
1841	29·679	30·211	29·679	0·532	·255	·417	·142
1842	30·082	30·485	29·141	1·344	·328	·447	·165
Means ..	29·957			1·281	·281		
Extremes	30·331 29·646	30·729	28·910	1·687 0·532	·338 ·212	·447	·084

TEMPERATURE.				DEW-POINT.					Date.
Diff.	Mean Min. Shade.	Mean Min. Rad.	Diff.	Mean.	Max.	Min.	Mean Dryness.	Greatest Dryness.	
°	°	°	°	°	°	°	°	°	
6	39·40	35·00	4·40	42·80	54	27	1·30	7	1826
8	39.70	35·10	6·60	44·20	54	27	1·20	8	1827
9	39·30	34·30	5·00	44·70	54	28	1·61	8	1828
3	29·35	24·58	5·77	32·40	48	17	1·62	8	1829
4	30·58	26·29	4·29	34·90	49	12	1·25	11	1830
8	37·51	33·06	4·45	42·40	56	28	0·29	4	1831
7	36·29	31·64	4·65	41·80	56	29	0·19	4	1832
6	39·67	36·00	3·07	44·80	56	32	1·08	8	1833
9	35·16	30·67	4·49	40·80	54	27	0·35	10	1834
7·6	29·56	24·59	4·97	34·80	52	18	0·21	4	1835
7·5	35·51	32·09	3·42	39·90	56	24	0·34	6	1836
8·1	36·14	32·58	3·56	40·60	55	27	0·61	8	1837
7	32·71	28·54	4·17	38·68	54	30	0·26	9	1838
6	35·25	31·74	3·51	39·98	56	27	0·57	7	1839
5	26·45	22·48	3·97	31·55	56	16	1·11	14	1840
7	33·38	30·07	3·31	40·53	54	25	0·43	5	1841
4	38·35	35·48	2·87	44·02	56	29	0·16		1842
	34·96	30·83	4·13	39·99			0·74		Means
9	39·70	36·00	6·60	44·80	56		1·62	14	Extremes
	26·45	22·48	2·87	31·55		12	0·16		

SATURATION.			WINDS. No. of Days in the Month during which each Wind prevails.								Date.
Mean.	Lowest.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	
957	790	1·77	2	1	0	1	9	2	17	9	1826
964	763	3·09	1	0	0	1	5	9	10	5	1827
931	752	1·77	0	2	2	3	9	6	9	0	1828
931	759	0·15	3	10	7	4	0	4	2	1	1829
959	677	1·54	4	2	6	4	0	5	5	5	1830
987	868	2·38	1	2	0	1	5	17	3	2	1831
993	869	1·88	4	0	4	0	3	11	7	2	1832
962	745	4·29	0	0	0	1	1	15	12	2	1833
982	705	0·74	3	8	0	3	1	9	6	1	1834
991	890	0·25	3	3	0	0	10	10	2	3	1835
985	645	1·48	3	6	0	0	2	14	4	2	1836
972	751	1·35	1	6	1	2	8	8	4	1	1837
991	876	1·72	4	1	0	8	1	6	7	4	1838
972	772	2·32	1	2	3	8	7	5	3	2	1839
959	606	0·45	2	12	3	2	2	3	4	3	1840
984	828	2·12	1	3	0	3	2	10	10	2	1841
994	876	0·76	0	0	0	2	12	8	9	0	1842
971	774	1·65	1·9	3·4	1·5	2·5	4·5	8·3	6·1	2·5	Means
994		4·29	4	12	7	8	12	17	17	9	Extremes
931	606	0·15	0	0	0	0	0	2	2	0	

Months.	TEMPERATURE.								
	Mean Shade.	Max. Shade.	Max. Sun.	Greatest Diff.	Mean Max. Shade.	Mean Max. Sun.	Mean Diff.	Min. Shade.	Min. Rad.
	°	°	°	°	°	°	°	°	°
January	36·02 –	60	70	16	41·10 –	44·70 –	3·68	–4·5 –	–12 –
Feb.	39·75	65	80	18	45·94	52·36	6·42	10	4
March	42·96	75	97	28	50·86	60·84	9·98	19	8
April	47·57	78	105	27	57·14	68·39	11·31	16	8
May	55·26	86	126	40	66·02	83·20	17·18	26	16
June	60·68	93	125	38	71·69	89·71	18·60	35	26
July	63·17 +	94·40 +	130 +	40 +	74·09 +	93·51 +	19·42 +	37·4 +	31·1 +
August	62·78	93	120	37	73·58	91·58	18·00	36	29
Sept.	57·00	84	113·9	30·6	67·05	83·16	16·11	29	23
October	50·37	80	107	36	59·16	71·26	12·10	20	12
Nov.	43·12	63	80	19	50·44	56·03	6·23	15	10
Dec.	40·09	61	69	13 –	45·47	48·95	3·48 –	10	8·6
Means	49·88				58·54	70·30	11·87		
Extremes	36·02	94·40	130	40	41·10	93·51	19·42		31·1
	63·17			13	74·09	44·7	3·48	–4·5	–12

Months.	BAROMETER.				FORCE OF VAPOUR.			* Evapn.
	Mean.	Highest.	Lowest.	Range.	* Mean.	Highest.	Lowest.	
January	29·952	30·856 +	28·720	1·438 +	·228 –	·447	·051 –	0·620
Feb.	29·926	30·665	28·597 –	1·360	·248	·463	·084	0·840
March	29·935	30·726	28·655	1·209	·263	·514	·092	1·643
April	29·919	30·578	28·910	1·099	·286	·699	·078	2·520
May	29·959	30·548	29·197	0·952	·381	·723	·142	3·999
June ...	29·970	30·489	29·253	0·840	·446	·826	·224	3·750
July	29·952	30·475	29·266	0·808 –	·482 +	·973 +	·224	4·247 +
August	29·971 +	30·460	28·985	0·943	·479	·882	·251	4·030
Sept.	29·882	30·594	28·744	1·067	·407	·854	·216	3·030
October	29·949	30·713	28·802	1·273	·336	·632	·142	2·139
Nov.	29·834 –	30·578	28·669	1·377	·279	·532	·112	1·170
Dec.	29·957	30·729	28·910	1·281	·260	·447	·084	0·620 –
Means	29·933			1·137	·342			2·833
Extremes	29·971	30·856		1·438	·482	·973		4·247
	29·834		28·597	0·808	·228		·051	0·620

* See Note, p. 366.

TEMPERATURE.				DEW-POINT.						
Greatest Diff.	Mean Min. Shade.	Mean Min. Rad.	Mean Diff.	* Mean.	Max.	Min.	* Mean Dryness.	* Greatest average daily Dryness.	Greatest Dryness.	Months.
°	°	°	°	°	°	°	°	°	°	
12	30·99 –	26·40 –	4·50	33·49 –	56	0 –	2·53 –	5·10 –	17	January
11·7	33·67	28·59	5·08	35·98	57	12	3·77	7·44	17	Feb.
13+	35·41	30·13	5·28	37·82	60	14	5·14	10·63	29	March
12·1	37·75	32·24	5·51	40·57	69	10·5	7·00	13·74	35·5	April
12	43·56	37·97	5·59+	46·79	70	25	8·47+	15·99+	43·0+	May
11	49·89	44·92	4·95	53·16	74	37	7·72	15·26	36	June
10	51·95+	47·79+	4·18	55·37+	79+	37·5	7·80	15·29	38	July
10	51·72	46·88	4·84	55·16	76	40	7·62	14·98	28	August
9	47·17	42·94	4·23	50·49	75	36	6·51	14·24	29	Sept.
9	41·99	37·36	4·63	45·64	66	25	4·73	9·85	16	October
10	36·93	32·48	4·14	39 87	61	19	3·25	7·62	16	Nov.
9	34·96	30·83	4·13 –	37·47	56	12	2·62	5·46	14	Dec.
	41.33	36.54	4.75	44·31			5·59	11·3		Means
13	51·95	47·79	5·59	55·37	79		8·47	15·99	43	Extremes
	30·99	26·40	4·13	33·49		0	2·53	5.10		

SATURATION.				WINDS. No. of Days in each Month during which each Wind prevails.								
* Mean.	Lowest.	* Mean daily Minimum.	Rain in Inches.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Months.
919	550	849+	1·56	2·8	4·7	3·7	2·4	4·5	5·7	4·0	2·9	January
892	550	758	1·45	2·2	3·3	3·2	2·0	4·4	5·8	5·1	2·1	Feb.
832	358	704	1·36 –	2·5	4·8	2·9	1·8	3·2	6·5	6·0	3·0	March
773	289	627	1·55	4·0	4·9	3·5	2·1	3·4	5·0	3·5	3·1	April
752 –	235 –	590 –	1·67	2·4	6·4	5·2	1[illegible]	5·0	5·1	3·1	1·5	May
763	300	614	1·98	1·4	3·4	2·3	1·4	4·7	7·1	6·2	3·0	June
779	273	613	2·44	1·2	2·1	2·8	0·9	4·1	9·0	7·1	2·8	July
786	324	631	2·37	1·2	3·2	2·8	1·1	5·2	7·4	7·2	2·7	August
801	390	652	2·97+	1·5	3·1	2·7	1·5	6·4	6·3	6·1	2·1	Sept.
830	506	710	2·46	1·6	3·7	2·5	1·5	6·1	6·6	5·4	3·2	October
878	594	773	2·58	1·2	3·8	3·2	2·2	5·2	7·1	4·4	2·6	Nov.
928+	606	810	1·65	1·9	3·4	1·5	2·5	4·5	8·3	6·1	2·5	Dec.
827		677	2·013									Means
928		849	2·97									Extremes
752	235	590	1·36									

[For reasons given at p. 318, the columns to which an asterisk is prefixed have been recalculated in the manner there described, and the results obtained embodied in the text. In the preceding Table, in order that the maxima and minima may be rendered more evident to the eye, and that the months in which they occur may be at once visible, all the maxima are distinguished by the sign +, which is subjoined to them, and the minima are similarly indicated by the sign -. The general means being obtained by a different method, sometimes vary a little from those quoted in the Essay.]

AN ESSAY

ON SOME OF THE

PHENOMENA OF ATMOSPHERIC ELECTRICITY.

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THE capital discovery of Franklin of the identity of lightning with the electric discharge, is known to all the world: and every body is aware that, after an accumulation of clouds has, under certain circumstances, taken place, and these clouds have approached towards the earth, a flash between the two sometimes occurs, attended with precisely the same phenomena as those which result, in a minor degree, from the explosion of a charged electrical jar or battery. Franklin's experiment with the kite, and the contemporaneous experiments of Dalibard with an insulated metallic rod, seemed to be the commencement of a course of investigation which could not fail to explain both the causes and effects of atmospheric electricity; but the results have not accorded with the anticipation; for, on account both of the peculiar difficulties attending upon the inquiry, and the want of systematic and co-operating observa-

tions, which it is out of the power of individual exertions to institute, we are more in the dark respecting this subject of surpassing and exciting interest, than with regard to most other branches of natural philosophy.

The electrical kite has often since been raised by other experimenters, but with scarcely any other result than a confirmation of Franklin's conclusions, with more or less striking phenomena. There is little difficulty in performing the experiment, but it is not unaccompanied with danger in unskilful hands. The kite may be raised by its string precisely in the state in which boys are wont to use it; but to a loop two or three yards below the kite is tied a conducting wire, consisting of a fine lace thread, which is let out from an insulated reel by a person placed to leeward. By this management, the conducting thread hangs as nearly perpendicular as possible from the string, which must also be insulated when let out to a sufficient length. This apparatus affords the most likely method of obtaining satisfactory observations on the electricity given to the air, by the passage of clouds. A rapid succession of discharges is also frequently obtained from it both during hot hazy days, when no cloud is visible, and also occasionally in cold dense fogs in winter.

A more permanent apparatus is however absolutely necessary for a regular systematic course of observation upon the electricity of the atmosphere; and scarcely any essential improvement has yet been made in that of Mr. Read, who, in the years 1790 and 1791, accumulated a valuable mass of facts on the subject, which

are recorded in the 82nd volume of the *Philosophical Transactions.*

A new mode of insulation was described by Mr. Francis Ronalds, in the *Quarterly Journal of Science* for 1817, which has lately been applied with the most perfect success to atmospheric conductors, both at the Meteorological Observatory of the British Association at Kew, and at the Royal Observatory at Greenwich. The following brief account of the arrangements at the former station, may be taken as a model of the most perfect apparatus which our present knowledge of the subject will perhaps allow of our constructing.

The dome in which an equatorial was formerly placed, has been converted into the electrical observatory. A circular pedestal, about eight feet in height, is firmly fixed in the middle of the room, and a platform, which is ascended by a few steps, surrounds the pedestal, so that the operator standing upon it, shall be at a convenient height to adjust and observe the various instruments. At the centre of the pedestal is fixed a strong glass pillar, supporting a vertical copper tube, tapering upwards; the length of this conductor is twenty feet,—sixteen feet being elevated above the dome in the open air. The lower part of the conductor within the dome carries four horizontal branches, placed at right angles to each other; these are for the purpose of bringing into connection with the conductor the various electrometrical instruments employed. The electricity of the atmosphere is collected by means of a lamp-flame constantly maintained both night and day, and placed at the upper extremity

of the conductor; by this plan, which Volta recommended, much more electricity is collected than by means of a metallic point; the lamp is lowered and elevated when required, by means of a cord and pulley contained within the tube.

The insulation of the conductor is preserved by the effective method proposed by Mr. Ronalds. The insulating glass support has in its interior a hollow conical space, the base of which opens into the pedestal; beneath this opening is placed a small night lamp, which heats the air within the cone, and raises the temperature of the glass pillar. The upper part of the external surface of this pillar is not sufficiently heated to prevent the deposition of moisture, and is therefore, to a certain degree, a conductor; the lower part also conducts slightly on account of its elevated temperature; but there is a zone between these two parts, which insulates perfectly on account of the temperature of that part of the surface being sufficient to expel all moisture, and yet not sufficient to enable it to conduct. A conductor thus insulated, will retain its charge for hours without sensible diminution.

Another peculiarity and advantage of this method of insulation is, that the active parts of all the electrometers are suspended from the conductor, and are therefore uniformly charged, depending for their insulation on the warmed glass pillar only, and not, as usual, upon separate insulators, which dissipate the electricity unequally.

A discharger in good substantial metallic communication with the ground, is placed in such a way as to

act on Lane's electrometer for measuring the length of sparks in high states of intensity, and also as a safety valve in case of any dangerous increase of the same.

For occasional observations, a jointed fishing-rod may be employed, terminating in a well-varnished rod of glass, to the end of which is fixed the pointed end of a metallic wire, communicating at the other end with the electrometer. The power of this collecting rod may be increased by the flame of spirit of wine, contained in a piece of cotton fixed in a small spiral of wire at its highest extremity.

Any delicate well-insulated electrometer may be employed with this apparatus; but perhaps none is preferable to the common pith-ball electrometer, used both by De Saussure and Volta, with a graduated quadrant, by which the repulsion of the balls may be measured. In very delicate experiments, the observation may be made with a telescope armed with a micrometer.

Saussure made use of very simple means to determine the relation of the intensity of the charge to the distance of the balls. He took two electrometers, as nearly alike as possible, and electrified one of them till the balls repelled each other to a distance of six lines. He then touched the cap of the charged electrometer with the cap of the uncharged one, and thus divided the charge equally between them: the divergence of each was then found to be four lines. A diminution of half the charge was thus found to produce only a reduction of one-third of the repulsion. Upon again discharging one of the instruments, and renewing the

contact with the other, the divergence was 2·8. Upon again repeating the experiment, it fell to 1·9. He thus formed experimentally a table of the value of the degrees of each instrument, which every systematic observer should be at the pains to do.

The galvanometer has also been adapted by M. Colladon to atmospheric observations. For this purpose, it must consist of a fine wire of at least 500 coils perfectly insulated. The wire being first well covered with white silk, is placed in a strong solution of lac in alcohol, and then slowly coiled round the case of the instrument. It thus becomes gradually coated with an insulating varnish, much more efficacious than the silk alone. In using this apparatus, one of the ends of the wire is connected with the metallic conductor employed for collecting the electricity from the air, and the other is put in communication with the ground. The current produced by the flow of the electricity through the wire in its passage from the air to the earth causes the magnetic needle to deviate a number of degrees dependent upon its quantity.

From repeated and long experience Mr. Read was perfectly satisfied that the aqueous particles suspended in the air are constantly electrified, requiring only the aid of a proper collector to render the effects of their electricity at all times sensible*. During a course of moderate weather, the electricity of the atmosphere is invariably positive; and exhibits a flux and reflux, which generally causes it to increase and decrease

* *Phil. Trans.*, vol. lxxxii. p. 225.

twice in every twenty-four hours. The moments of its greatest force are about two or three hours after the rising, and some time before and after the setting of the sun; those when it is weakest are from mid-day to about 4 o'clock. The periodical electricity of the atmosphere seems to be manifestly influenced by the rise and fall of temperature. Warm small rain is always weakly electrified; and cold rain, which falls in large drops, is the most intensely electrified of any.

The following Table of the results of a twelvemonth's observations is taken from Mr. Read's paper.

TABLE XLV.

	Positive.	Negative.	Sparks drawn.
May, 1791 .	40 times	27 times	13 days
June . .	45	22	5
July . .	36	23	8
August .	33	6	3
September .	39	11	19
October .	37	7	22
November .	30	8	11
December .	35	11	6
January, 1792	28	8	3
February .	36	12	6
March . .	34	8	2
April . .	30	14	8
	423 times	157 times	106 days.

From an attentive examination of the whole of Read's observations, Mr. Luke Howard has derived the following general results* :—

* *Climate of London*, 2nd ed., vol. i. p. 145.

1. The positive electricity common to fair weather often yields to a negative state before rain.

2. In general the rain that first falls after a depression of the barometer is negative.

3. Above forty cases of rain in one hundred give negative electricity; although the state of the atmosphere is positive before and afterwards.

4. Positive rain in a positive atmosphere occurs more rarely; perhaps fifteen times in one hundred.

5. Snow and hail, unmixed with rain, are positive, almost without exception.

6. Nearly forty cases of rain in one hundred affected the apparatus with both kinds of electricity; sometimes with an interval in which no rain fell; and so that a positive shower was succeeded by a negative, and *vice versa:* at others, the two kinds took place during the same shower.

Mr. Read frequently observed that on some days the pith-balls exhibited a series of rapid changes, to account for which he was for a long time extremely puzzled. They were positive for one minute, then negative for another, and the next returned again to positive. He seems, however, to have referred them to the right cause, and one which probably has not been sufficiently taken into account in similar observations; namely, an inductive influence upon the apparatus. To this we shall again advert.

The observations of Schübler, of Stuttgard*, which he made in the valleys of the South of Austria, from

* *Bibl. Univ.*, vol. xlii. p. 203.

May, 1811, to June, 1812, several times in each day, are, perhaps, the most accurate and systematic which, till very recently, have yet been made upon the electricity of the atmosphere. They not only confirm the general conclusions of Read, but indicate with more precision the exact hours of the maxima and minima of intensity, and the changes which they undergo with the various seasons.

We will endeavour to point out the laws which may be deduced from them by means of the following Tables.

The first exhibits the observations made on the 11th May, 1811, at short intervals during a perfectly serene state of the weather, which lasted the greatest part of the day: the second includes observations at five different hours of each day, in the months of October and November of the same year; and the third gives a general summary of all the observations made from May, 1811, to June, 1812.

TABLE XLVI.

Hour.	Electrometer.	Hygroscope.	Thermometer.	Weather.
4 A.M.	+ 5	88		Perfectly serene: the sky became gradually misty. Dew was formed.
5	+ 6½	88		
6	+ 8	87		
7	+11	86		
8	+13	84		
9	+10	76		The horizon became perfectly clear, and of a pure blue colour.
10	8	70		
12	7	63		
2 P.M.	6½	61		
4	5½	60		
5	5	62		
6	+ 6	65		Became again misty, and the dew of evening formed.
7½	+ 8	72		
8½	+12	83		
9½	+ 8	86		Perfectly serene.
10½	7	88		
12	6½	88		

TABLE XLVII.

INTENSITY OF ELECTRICITY.

OCTOBER.

	7 a.m.	8½ a.m.	2 p.m.	7 p.m.	10 p.m.	
1	+ 8	+19	+ 8	+20	+ 5	Calm, hot.
2	+ 8	+ 8	+38	+16	+11	At 2 p.m. light stormy clouds, with some rain.
3	+ 7	+18	+ 9	+15	+ 5	Serene and clear.
4	+ 6	+14	+ 6	+38	+ 3	Morning clear; rain at 7.
5						
6						
7						
8	+10	+ 7	+ 4	+25	+ 8	Cloudy morning; clear and starlight night.
9						
10						
11	+ 5	+17	+ 5	+22	+10	Clear.
12						
13	−14	0	+ 6	+17	+ 6	A little rain till 8; night clear.
14						
15						
16	+ 8	+15	+ 9	+22	+11	Clear.
17						
18						
19						
20						
21						
22	+ 7	+13	+ 5	+27	+10	Clear; fog at 7 p.m.
23						
24						
25						
26						
27	−20	−14	0	− 2	−40	South wind and rain; high barom.
28	+ 7	+ 9	+ 6	+30	+ 8	Changeable, clear; fog at 7 p.m.
29	+ 4	+ 5	− 60	+14	+ 5	Cloudy; hard rain at 2; night clear.
30	+ 5	− 6	+ 5	− 6	− 4	Cloudy morning; afternoon, rain.
31	+ 5	+ 7	+20	+ 9	+ 5	Cloudy, a little rain at 2, then clear.

NOVEMBER.

	7½ a.m.	9 a.m.	2 p.m.	6½ p.m.	10 p.m.	
1	+ 5	+ 7	+ 6	+12	+ 5	Cloudy morning, clear night.
2	4	14	5	20	7	Clear, afterwards some clouds.
3	5	13	5	30	10	Clear and hot.
4	5	13	8	20	2	Clear; cloudy evening; therm. at 2.
12	4	5	− 50	7	4	Cloudy; rain in the afternoon.
15	4	0	+ 3	−20	3	Cloudy; rain in the afternoon.
19	6	20	28	+17	7	Clear, cold, fog.
22	7	13	7	14	6	Clear, cold.
26	10	13	15	17	11	Changeable, cloudy, fog.
27	7	13	20	14	17	Cloudy, with some fog.
28	11	14	9	17	5	Generally cloudy; wind north, without being very cold.
29	7	7	15	13	4	
30	3	4	21	13	8	

TABLE XLVIII.

Month.	Weather.	Hours.	First Minimum at Sunrise or a little after.	Hours.	First Maximum after Sunrise.
			A.		B.
June, 1811....	Serene.	4 to 5 a. m.	+ 5·64 + 3·40 + 4·80	5½ to 6 a.m.	+12·85 + 8·20 +10·48
July	Do.	5 a. m.	+ 4·87 + 4·00 + 4·63	6½	+13·50 + 6·75 +11·65
August	Do.	5 a. m.	+ 5·87 + 5·00 + 5·73	7½	+15·93 + 8·33 +14·75
September....	Do.	7 a. m.	+ 5·54 + 5·50 + 5·53	8	+15·43 + 8·00 +13·95
October........	Do.	7 a. m.	+ 7·25 + 5·20 + 6·40	8½	+15·35 + 8·12 +12·22
November....	Do.	7 a. m.	+ 5·50 + 6·00 + 5·85	9	+14·42 + 7·86 + 9·95
December....	Do.	8 a. m.	+12·40 + 8·93 + 9·80	10	+18·80 +12·00 +13·70
Jan. 1812	Do.	7 a. m.	+14·75 + 9·75 +10·71	10	+31·00 +14·00 +17·23
February	Do.	7 a. m.	+ 7·54 + 6·60 + 6·66	9	+25·55 + 9·60 +18·90
March	Do.	6½ a. m.	+ 5·37 + 3·00 + 3·36	8½	+13·00 + 6·16 + 8·92
April...........	Do.	6	+ 4·00 + 3·00 + 4·36	8	+14·75 + 6·50 +12·90
May	Do.	5	+ 4·15 + 3·50 + 4·08	7	+13·00 + 6·00 +11·27
Means of the 12 Months	Do.	....	+ 6·90 + 5·32 + 5·99	....	+16·95 + 8·46 +12·16

TABLE XLVIII. *continued.*

Hours.	Second Minimium from 2 to 4 p.m.	Hours.	Second Maximum after Sunset.	Ratio of the Electric Force during Maximum and Minimum.	Mean Electric Force.	Highest Force during Serene Weather.
	A′.		B′.			°
2 p.m.	+ 3·92	10p.m.	+12·00	1 : 2·87	+ 8·60	+16
	+ 3·83		+ 7·83	1 : 2·13	+ 5·67	
	+ 4·22		+10·44	1 : 2·31	+ 7·62	
2	+ 4·56	9½	+14·43	1 : 2·96	+ 9·50	+22
	+ 4·00		+ 7·00	1 : 1·71	+ 5·35	
	+ 4·42		+12·05	1 : 2·49	+ 8·35	
2	+ 5·47	8½	+16·11	1 : 2·82	+10·84	+25
	+ 4·66		+10·00	1 : 1·89	+ 6·99	
	+ 5·35		+15·20	1 : 2·70	+10·25	
2	+ 5·00	8	+15·61	1 : 2·94	+10·39	+25
	+ 3·50		+ 9·00	1 : 1·88	+ 6·33	
	+ 4·76		+14·80	1 : 2·79	+10·25	
2	+ 6·28	7½	+19·71	1 : 2·59	+12·83	+28
	+ 4·83		+ 8·00	1 : 1·60	+ 6·42	
	+ 6·03		+18·60	1 : 2·47	+10·13	
2	+ 8·22	7	+17·44	1 : 2·32	+11·77	+30
	+ 8·50		+10·66	1 : 1·27	+ 8·13	
	+ 8·40		+13·57	1 : 1·64	+10·73	
2	+12·85	6	+20·71	1 : 1·56	+16·29	+35
	+15·31		+19·41	1 : 1·29	+14·12	
	+14·56		+19·84	1 : 1·37	+14·72	
2	+19·10	6	+31·83	1 : 1·85	+24·45	+40
	+16·86		+25·04	1 : 1·48	+16·12	
	+17·52		+27·50	1 : 1·58	+18·13	
2	+16·27	7	+24·54	1 : 1·93	+18·47	+55
	+ 8·50		+13·10	1 : 1·50	+ 9·70	
	+11·30		+19·80	1 : 2·03	+14·10	
2	+ 6·42	7½	+14·00	1 : 2·29	+ 9·69	+21
	+ 3·83		+ 7·40	1 : 1·98	+ 5·00	
	+ 5·80		+ 9·66	1 : 2·02	+ 6·93	
2	+ 4·75	8½	+ 7·58	1 : 2·55	+ 7·77	+25
	+ 3·50		+ 5·50	1 : 1·84	+ 4·62	
	+ 4·63		+ 7·36	1 : 1·25	+ 7·31	
2	+ 4·33	9	+10·27	1 : 2·75	+ 7·93	+20
	+ 4·50		+ 5·80	1 : 1·47	+ 4·95	
	+ 4·36		+10·00	1 : 2·53	+ 7·41	
....	+ 8·09	....	+17·01	1 : 2·27	+12·23	+55
	+ 6·81		+10·73	1 : 1·58	+ 7·83	
	+ 7·61		+14·97	1 : 1·99	+10·82	

From the observations of Table XLVI. we learn that there is a first minimum of intensity at 4 A.M., and a first maximum at 8 A.M.; a second minimum at 5 P.M., and a second maximum at 8½ P.M.

Table XLVII. shews that these maxima and minima vary a little in the exact hours of their recurrence; but in taking the means of whole months we may obtain results which may be perfectly relied upon.

M. Schübler remarks that the electric periods are marked with the greatest intensity on days of perfectly hot and dry weather, when luminous streams have been observed in the air bearing some analogy to those of the aurora borealis.

In columns A B, and A′ B′, of Table XLVIII. are inscribed the mean values of the maxima and minima of each month, as well as the hours on which they fall. In each column there are three groups of figures, which indicate the maxima, minima, and mean amounts. From June, 1811, to January, 1812, it will be seen that the hour of the minimum continually advanced, while from January to May it receded.

The same observation, with two or three trifling exceptions, may be made with regard to the hour of the first maximum; but the epoch of the second minimum appears to be invariable, while the last maximum follows a course inverse to that of the first.

We find, moreover, that the electric force, both for the maxima and minima, increases from the month of July to the month of January inclusive; so that the greatest intensity takes place in winter and the least in summer, and in calm weather in winter the increase

of electricity is always proportioned to the increase of cold. The means of the twelve months placed at the bottom of the Table, moreover show that the intensity of the first minimum and maximum is something lower than that of the second.

The accuracy of these observations has since been confirmed by M. Arago, who, moreover, found that sparks of electricity might sometimes be drawn from the conductor in perfectly serene weather.

I will now present in a Table a recapitulation of the observations made by M. Schübler, at Stuttgard, in times of rain, snow, and storms, during the same twelve months.

TABLE XLIX.

	ELECTRICITY DURING RAIN AND SNOW.				ELECTRICITY IN CLOUDY WEATHER.		Mean Temp. and Rain during the Month.
	HIGHEST DEGREE OF ELECTRICITY.		MEAN DEGREE.				
	Positive.	*Negative.*	*Positive.*	*Negative*	*Mean.*	*Max.*	
June	+ 400 during a storm on the 1st; rain and hail at 5 p.m.	— 600 during a storm on the 30th; hard rain, alternated with + 400.	+ 235 during 9 days.	— 2[illegible] in[illegible] ys.	+ 16	+ 20, on the 23rd.	5·71 ins.
July	+ 600, on the 3rd, at 4 p.m., with a violent storm.	— 500, on the 16th; storm and rain, at the beginning + 50.	+ 400 during 5 days.	— 280, during 5 days.	.. ..	.. ..	1·05 ins.
Aug.	+ 500, on the 20th, a.m. 7, with a storm and rain which extended very far.	— 140, on the 28th, 4 p.m., with rain.	+ 290 during 7 days.	— 80, during 7 days.	+ 25	+ 30, 10th, 7 a.m.	1·66 ins.
Sept.	+ 30 on the 27th, 7 p.m.; small rain.	— 10, on the 25th, 11 a.m.; small rain.	+ 30 during 1 day.	— 10, during 2 days.	+ 20·5	+ 25, 18th, a.m.	0·70 ins.
Oct.	+ 38, on the 4th, 7 p.m.; rain.	— 60, on the 29th, 2 p.m.; hard rain.	+ 26 during 5 days.	— 31, during 6 days.	+ 18	+ 30, 28th, 7 p.m.	1·89 ins.
Nov.	+ 55, on the 11th, 5 p.m.; hard rain.	— 50, on the 12th, 2 p.m.; rain.	+ 24, twice with rain, once with snow.	— 25, 3 times with rain.	+ 18·1	+ 28, 19th, 2 p.m.	0·84 ins.
Dec.	+ 60, on the 23rd, 6 p.m., with wind and snow.	— 400, on the 24th, 2 p.m., with wind and rain.	+ 32, 9 times with snow, once with rain.	— 157, 3 times with rain.	+ 32·7	+ 36	1·42 ins.
Jan.	+ 70, on the 13th, 2 p.m., with much snow.	— 20, on the 21st, 7 p.m., with snow alternated with + 20.	+ 40, 7 times with snow.	— 17·2, twice with snow, once with rain.	+ 34·1	+ 44, 30th, 6 p.m.	1·06 ins.
Feb.	+ 90, on the 16th, 7 p.m., with snow and rain.	— 150 on the 16th, 5 p.m., with rain, alternate with +.	+ 41, twice with rain, once with snow.	— 44, 8 times rain, once snow.	+ 33·2	+ 55, 4th, 7 p.m.	1·72 ins.
March	+ 200, on the 5th, 2 p m., with snow and hail.	— 340 on the 22nd, 5 p.m.; hard rain, alternate with + 110.	+ 74, 6 times with rain, twice with snow.	— 65, 8 times with rain. 8 times with snow.	+ 21·0	+ 21, 20th, 9 a.m.	1·61 ins.
April	+ 50, on the 9th, 2 p.m., with snow.	— 80 on the 22nd, 8 p.m., with rain.	+ 40, 4 days with snow.	— 58, 5 days with rain.	+ 15·5	+ 17, 7th, a.m.	1·26 ins.
May	+ 600, on the 16th, 8 a.m.; storm, with hard rain.	— 600 on the 29th, 8 p.m.; violent storm and tempest, with rain.	+ 186, 9 days with rain.	— 179, 6 days with rain.	+ 14	+ 14, 20th, a.m.	2·14 ins.
Mean	+ 600.	— 600. — 245.	+ 117, during 71 days.	— 101, during 69 days.	+ 22·5	+ 55	21·06 ins.

On examining the results recorded in this Table and comparing them with that in Table III., we find that the electricity of the atmosphere in cloudy weather is still positive, and more intense in winter than in summer; that, during storms, or when it rains or snows, it is sometimes positive, sometimes negative, and much stronger than in fine weather.

The days of positive precipitations were 71, of negative 69; so that the days of positive and negative may be said to be sensibly equal.

It often happens that the electricity changes its sign many times in the same day; a remark which has been made both by Arago and De Saussure. The former observed 11, and the latter 14 such changes during storms.

The periodical increase and decrease of intensity is so regular as evidently to be connected with the position of the sun above or below the horizon, and is probably directly dependent upon the ultimate tendencies to precipitation and evaporation produced by the regular changes of temperature communicated to the air. It should also be carefully remembered that similar and contemporaneous changes seem to affect the magnetic phenomena of the earth. The established connexion of the two forces gives an interest to such coincidences, from the attentive observation of which we may hope that light will be thrown upon their mysterious relations.

De Saussure found that the electricity of the air varies in different places; that it is strongest in high isolated situations; that it does not manifest any

activity in houses, under trees, in streets, or generally in inclosed parts. It may, however, be traced in the squares, and on the quays of bridges of large towns. In the latter situations he even found it stronger than in the open country.

M. Becquerel* found in serene weather, that the increase of intensity with the height, was very decided, and he established the fact in a very ingenious way. He ascended the Grand St. Bernard with M. Breschet, and upon one of the small plains in the neighbourhood of the Hospice they extended a piece of gummed silk three mètres long, and two wide, and disposed upon it a gilt silk thread eighty mètres in length. One of the ends of the thread was put in communication with the cap of the electrometer, by means of a running knot, and the other was attached to the shaft of an arrow, which was then shot into the air from a well-bent bow. The arrow, as it rose in the air, carried the thread with it, and detached it from the electrometer after it had been completely unrolled. The straws of the electrometer separated more and more as the arrow rose, and the repulsion was so strong, that they ultimately struck the sides of the glass by which they were covered. The conducting thread being separated from the electrometer, the instrument retained its charge, which was found to be positive. When the thread, instead of being attached to an electrometer, terminated in an insulated spiral, the electrical current was strong enough to magnetize small needles.

* *Traité de l'Electricité*, tom. iv. 110.

That the electricity was not produced by the friction of the arrow passing through the air, was proved by shooting the arrow in a horizontal direction, when no effect was produced upon the electrometer.

From these experiments, it is clear that the positive electricity with which the air is always charged in serene weather, increases upon high mountains from 3 feet to a height of about 250 feet above them. M. Becquerel, moreover, found that the conducting wire always indicated the same species of electricity, without any signs of a change from positive to negative. With regard to the sources from whence the air receives its electric charges, we are in a state of great ignorance and uncertainty.

Up to the time of the late experiments of Dr. Faraday upon the electricity of effluent steam, little doubt was entertained that the processes of evaporation and condensation were the most active in supply.

The occasional negative charges of the atmosphere it would be more difficult to account for, if the observation of M. Pouillet should be confirmed, that the evaporation of pure water is unaccompanied by any excitement of electricity. If this were not the case, the ultimate evaporation and precipitation of clouds in the upper atmosphere, might obviously produce strata in opposite states of charge. The influence of induction might indeed produce such alternations, and would very well account for the sudden changes which often take place in stormy weather. For suppose two strata of clouds above the earth, (and storms never take place unless more than one is present,) and the upper one to

be strongly electrified with a positive charge; the under one would be polarly charged by its influence. Its upper side turned towards the charged cloud would be in the negative state, and its under side towards the earth positive. If rain were now to begin to fall from the second cloud, it would reach the earth in positive drops; but if, while the process of precipitation continued, the influence of the first cloud were withdrawn or annihilated, the second cloud, having parted with its positive electricity, would remain in the negative state, and the rain which would subsequently fall, would consequently be found in the same state. The positive electricity of the cloud under induction might also pass off by a disruptive discharge, and leave it in the negative state, which, when the influence of the inducting cloud passed away, would leave the surrounding air in the same state. It is easy to perceive that in this way rapid alternations of the two states might readily occur.

Whether the processes of vegetation and vegetable evaporation have any influence upon the atmospheric charge is quite undecided; but that trees and other plants draw off the electricity of the air, and are perpetually tending to neutralize it with that of the earth, is a well established fact. Whether their own juices and secretions undergo any change during the process is, however, a point for further inquiry.

The theory which ascribes the development of atmospheric electricity to evaporation receives considerable support from the fact that the eruptions of volcanoes, in which enormous volumes of steam are discharged into the air and condensed, are constantly

accompanied by discharges of thunder and lightning, and the most violent storms occur at times, and in situations where the largest quantities of vapour are generated.

It is not difficult, upon the principles of electrical science, to form an idea of the process by which the intensity of electricity may accumulate upon a cloud till it reaches the point of disruptive discharge. Each of the first minute globules which are precipitated from the vapour will possess its own small share of electricity upon its surface, and as long as the globules remain isolated and thinly scattered there it will remain. When the globules begin to coalesce the electricity will still seek the surface of each increasing drop, and increase in intensity. When condensation takes place more rapidly the whole body of the cloud may be looked upon as a good conductor, and the electricity, as it is set free in the interior, will at once fly to the general surface, and by this process of concentration the force (which was at first, when diffused over a wide space, of low intensity,) acquires an enormous tension.

THE END.

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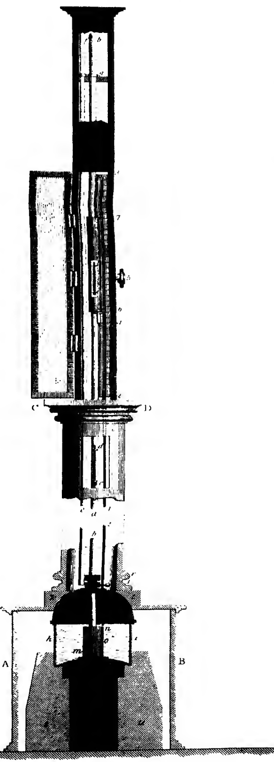

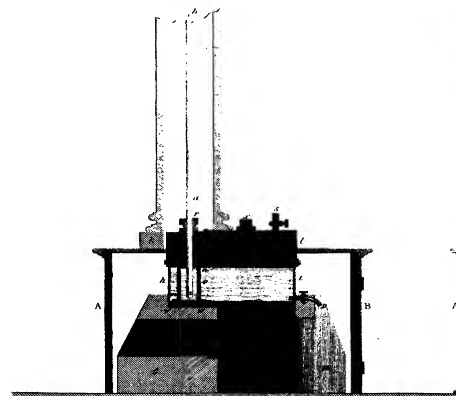

a b Barometer tube
c d Interior thermometer
e f Spare tube
g Collar
h i Steam boiler
k l Cover of the same
m n Interior Cylinder
o Small hole in the same
p Cock for drawing off water
r Stuffing box
s Steam cock
t u Fire place
v w Brick Screen
x Connecting screw
1 2 Brass rod of scale
3 Scale
4 Vernier
5 Pinion of rack
6 7 Brass screen with interior thermometer
A B Pedestal of Column
C D Capital of the same

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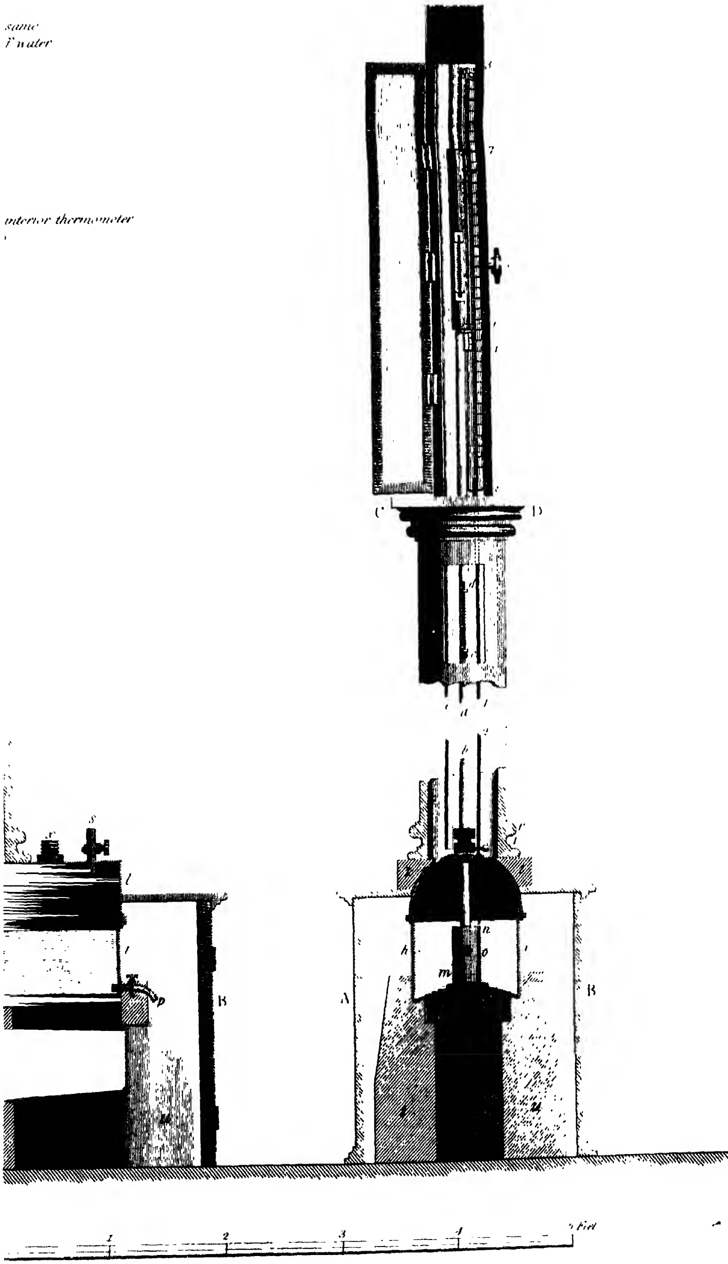

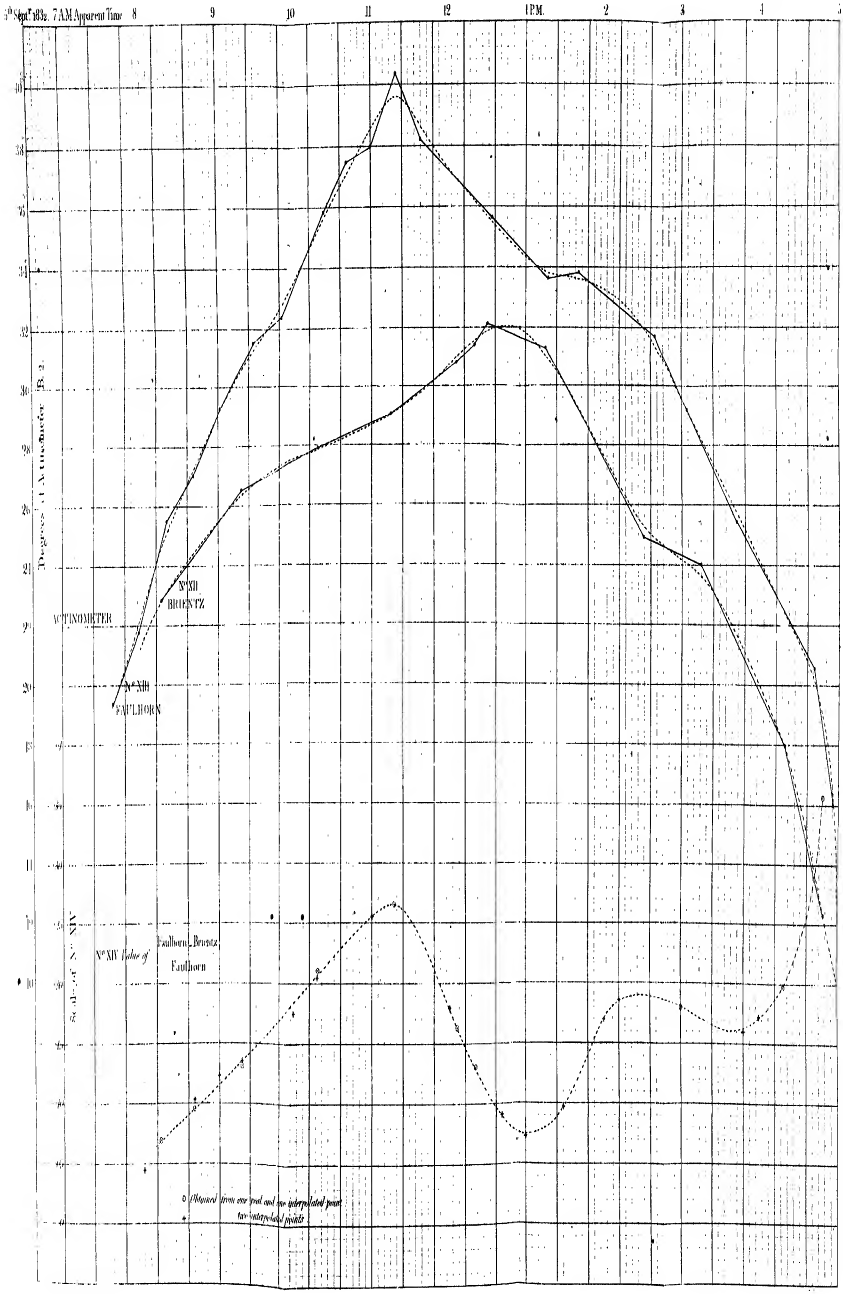
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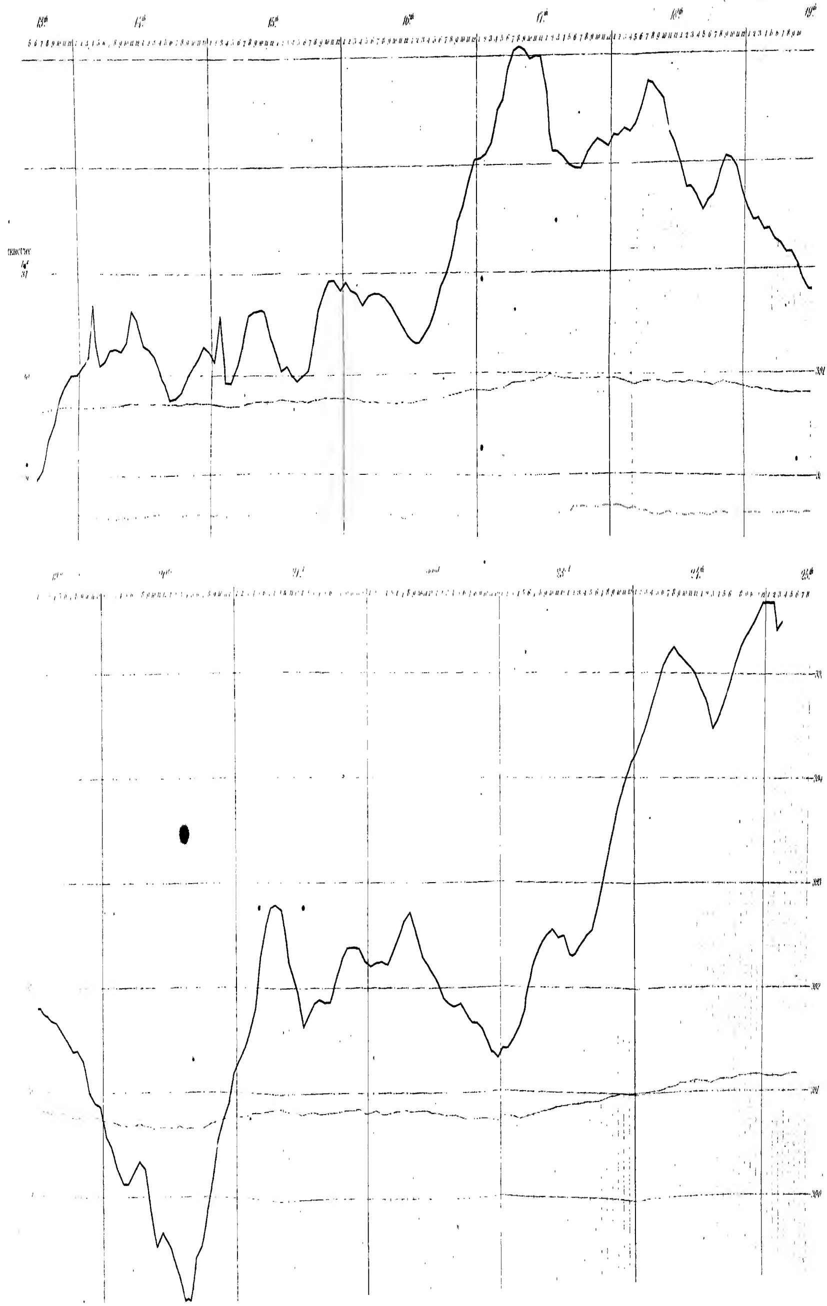
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